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A REVISION OF THE *AEDES SCUTELLARIS* GROUP OF TONGA (DIPTERA: CULICIDAE).

by

Yiau-Min Huang and James C. Hitchcock

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MEDICAL ENTOMOLOGY STUDIES - XII.

A REVISION OF THE *AEDES SCUTELLARIS* GROUP OF TONGA (DIPTERA: CULICIDAE).[1]

by

Yiau-Min Huang[2] and James C. Hitchcock[3]

ABSTRACT

This revision of the *Aedes scutellaris* group of Tonga is based on the examination of more than 9,000 specimens (including 1,866 individual rearings with associated pupal and/or larval skins) of 3 species and one subspecies. The group is defined and keys to the identification of the species of the group in the Fiji-Tonga-Samoa area are provided and their geographical ranges presented.

Aedes (Stegomyia) kesseli, a new species from Tafahi Island, is recognized. *Aedes cooki* Belkin (1962) is shown to be distinct and *Ae. tabu* Ramalingam and Belkin (1965) is considered a subspecies of *tongae* Edwards (1926).

The known stages of the 3 species and one subspecies in Tonga are described or redescribed and illustrated and information on type-data, distribution, bionomics, medical importance and a taxonomic discussion of all 4 species and subspecies are presented.

The male, female, pupa and larva of *kesseli* n. sp., the pupa and larva of *tongae tongae*, and the male, female and female terminalia of *cooki*, *tongae tabu* and *tongae tongae* are described and illustrated for the first time.

New records include: *cooki* from Niuafo'ou Island and Vava'u Group, *kesseli* from Tafahi Island and Niuatoputapu, *tongae tabu* from Pangaimotu

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[2]Medical Entomology Project, Department of Entomology, Smithsonian Institution, Washington, DC 20560.

[3]Formerly Scientist, Division of Malaria and Other Parasitic Diseases, World Health Organization. Present address: P. O. Box 1288, Nevada City, CA 95959.

Island, in Tongatapu Group, and *tongae tongae* from Lifuka Island, Luahoko Island, Ha'ano Island, Foa Island, Limu Island, Luangahu Island, Nukunamo Island, Tatafa Island, Tofanga Island, Uanukuhahake Island, Uanukuhihifo Island, Uiha Island, and Uoleva Island, in the Ha'apai Group.

Information is presented on the bionomics and medical importance of the above species and subspecies based on field studies conducted by James C. Hitchcock in Tonga from 1968-73. Special emphasis is placed upon immature habitats, relative abundance of each member of the group, composition of associated invertebrate fauna, biting behavior, fecundity and gonotropic cycle. The role of the *scutellaris* group in the transmission of filariasis and dengue viruses in Tonga is discussed.

INTRODUCTION

Members of the *scutellaris* group of the subgenus *Stegomyia* Theobald, genus *Aedes* Meigen serve as the primary vectors of subperiodic *Wuchereria bancrofti* (Cobbold) on many islands of the South Pacific. A thorough study to determine the species of mosquitoes present in the area and to develop adequate and reliable methods for recognizing them became evident and led to this taxonomic revision of the group in the area. The accompanying biological data was summarized from field observations conducted by the junior author during a 5 year period under the auspices of the World Health Organization (WHO).

The taxonomic study of the *scutellaris* group of the South Pacific at the Southeast Asia Mosquito Project (SEAMP) and later the Medical Entomology Project (MEP) directly related to the WHO *Aedes scutellaris* project in that area. It concentrated mainly on the Tonga area which is the most critical for a detailed study of the *tongae* complex. *Aedes tongae* Edwards is one of the most important vectors of subperiodic filariasis in the South Pacific. Unfortunately, there has been some taxonomic confusion in the past (see Huang 1972a, 1975). The present study clarifies the situation and also provides a better definition of the identity of these mosquitoes.

This study was based primarily on specimens accumulated by the Southeast Asia Mosquito Project and the Medical Entomology Project, Department of Entomology, Smithsonian Institution. Most of this material was from: (1) progeny rearings by SEAMP and MEP; (2) individual rearings and progeny rearings from the field made by James C. Hitchcock, World Health Organization; (3) individual rearings from the field made by James C. Hitchcock (personal collection). Unless otherwise indicated in the DISTRIBUTION sections, all individual rearings were conducted in the field. Additional material was borrowed largely from the John N. Belkin collection at the University of California at Los Angeles (UCLA)*, and a few from the British Museum (Natural History) (BMNH) and United States National Museum (USNM).

The nomenclature chosen for the chaetotaxy of the larva and pupa and the terminology of structural parts of the adult largely follows that of Belkin (1962) and Huang (1977b). Scientific names of plants have been verified in Yuncker (1959).

An asterisk (*) following the abbreviation used (♂ = male, ♀ = female, P = pupa, L = larva and E = egg) indicates that all or some portion of that sex

*In May 1976, the South Pacific Culicidae from this collection were transferred to the USNM.

or stage is illustrated. Abbreviations used for the references to the literature conform to the 1978 "Serial sources for the BIOSIS data base," BioSciences Information Service, Philadelphia, PA.

Distribution records are indicated as follows: Country names are in capital letters, island group and island names are in italics and place names have the first letter capitalized. The letters, l = larval skin, p = pupal skin and L = whole 4th stage larva.

The information on distribution presented in this paper is entirely based on specimens which we have examined.

The *Aedes scutellaris* group of Tonga is described. Three species and one subspecies of the *scutellaris* group, of which one species *(kesseli)* is described as new, 2 species *(cooki* and *tongae)* are revalidated, and one species *(tabu)* is reduced to subspecies status, are recognized from the Tonga islands. All known stages of the above species and subspecies are described or redescribed and illustrated. These 4 taxa are recorded for the first time from certain islands. Keys to the identification of the species of the *scutellaris* group in the Fiji-Tonga-Samoa area are provided and their geographical ranges are presented on Map VIII*.

DEFINITION OF THE *AEDES SCUTELLARIS* GROUP OF TONGA

The *Aedes scutellaris* group is characterized by the following combination of characters:

MALE. *Head.* Proboscis dark scaled, with or without some pale scales on the ventral side, slightly longer to longer than forefemur; palpus dark, slightly shorter to shorter than proboscis, with a white basal band on each of segments 2-5; those on segments 4, 5 dorsally incomplete; segments 4, 5 subequal, slender, upturned, and with only a few short setae; antenna plumose, shorter than proboscis; clypeus bare; torus covered with white scales except dorsally; decumbent scales of vertex broad and flat; erect forked scales dark, not numerous, restricted to occiput; vertex with a median stripe of broad white scales, with broad dark scales on each side interrupted by a lateral stripe of broad white scales followed ventrally by a patch of broad white ones. *Thorax.* Scutum with narrow dark scales and a distinct, median longitudinal stripe of narrow white scales; median stripe from anterior margin, narrowing slightly posteriorly and reaching beginning of prescutellar space; prescutellar line present or absent, with a few narrow golden yellowish scales or pale yellowish scales; posterior dorsocentral line present or well developed, with some narrow golden yellowish scales or pale yellowish scales; supraalar line with broad white scales; acrostichal bristles absent; dorsocentral bristles present; scutellum with broad white scales on all lobes and with a few broad dark scales at apex of midlobe; anterior pronotum with broad white scales; posterior pronotum with narrow dark scales on upper portion and with broad white scales on lower por-

*Editor's note: After this manuscript was completed, Hoyer and Rozeboom (1977) published a paper on the genetic affinities between several species or populations of the *Ae. (Stg.) scutellaris* group by comparison of insemination rates, fecundity, egg fertility and larva-to-adult survival of parental and crossbred populations. They indicated that 4 autogenous populations from Niue and the Tonga islands (*Ae. cooki, tongae tabu* and *kesseli* n. sp.) are closely related and belong to a single polymorphic species. -R. A. W.

tion forming a white stripe instead of a white patch; paratergite with broad white scales; postspiracular and subspiracular areas without scales; patches of broad white scales on propleuron, on the upper and lower portions of sternopleuron and on the upper portion of mesepimeron; lower mesepimeron with or without scales; upper sternopleural scale patch reaches to anterior corner of sternopleuron; lower mesepimeral scale patch of small, medium, or large size and well separated from, or narrowly connected to the upper mesepimeral scale patch; lower mesepimeron without bristles; metameron bare. *Wing.* With dark scales on all veins except for a minute basal spot of white scales on costa; cell R_2 about 1.5 length of R_{2+3}. *Halter.* With dark scales. *Legs.* Coxae with patches of white scales; knee spots present on all femora; fore- and midfemora anteriorly dark; hindfemur anteriorly with a white, longitudinal stripe which widens at base and is separated from apical white scale patch; all tibiae anteriorly dark; fore- and midtarsi with basal white bands on tarsomeres 1, 2, or sometimes on tarsomere 1 only; hindtarsus with basal white bands on tarsomeres 1-4; tarsomere 5 all white, or sometimes with a few dark scales at tip on ventral side; sometimes hindtarsus with basal white band on tarsomere 4 interrupted by a few dark scales on ventral side as well, or basal white bands on tarsomeres 4, 5 interrupted by a stripe of dark scales on ventral side; sometimes hindtarsus with basal white bands on tarsomeres 2-5 interrupted by a stripe of dark scales on ventral side; fore- and midlegs with tarsal claws unequal, the larger one toothed, the smaller one simple; hindleg with tarsal claws equal, simple. *Abdomen.* Segment I with white scales on laterotergite, with or without a median pale spot; tergum II with basal lateral white spots, with or without a basal median spot; terga III-VI each with a sub-basal median pale yellowish or white spot and with lateral white spots which are turned dorsomesally, or terga III-VI each with a complete or incomplete sub-basal white or pale yellowish band and with lateral white spots which are turned dorsomesally and connected to sub-basal white or pale yellowish bands; or terga III-VI each with a complete sub-basal transverse pale band and with lateral white spots which are connected to the tergal band; tergum VII with lateral white spots only, or with a sub-basal median spot as well, or with sub-basal transverse complete or dotted band; sternum VIII largely covered with white scales. *Terminalia.* Basimere 3.5-3.8 as long as wide, scales restricted to dorsolateral, lateral and ventral areas, with a patch of setae on the basomesal area of dorsal surface, mesal surface membranous; claspette simple, slender, sternal and tergal sides parallel, with modified setae, 4-7 in a row on apical 0.16-0.25 of sternal side, lateral surface with fine setae extending basad to about level of modified setae, or to 0.25-0.40 of the entire claspette length, apex tergally with setae about 0.5 length of entire claspette; distimere simple, elongate, length of basimere, with a spiniform process and a few setae near apex; aedeagus with a distinct sclerotized lateral toothed plate on each side; paraproct without teeth; cercal setae absent; apical margin of tergum IX with middle rounded or truncated and with a hairy lobe on each side.

FEMALE. Essentially as in the male, differing in the following respects: *Head.* Palpus 4-segmented, about 0.2 length of proboscis, with white scales on apical half, or less, or more. *Wing.* With cell R_2 about 2.0 length of R_{2+3}. *Legs.* Fore- and midlegs with tarsal claws equal, simple. *Abdomen.* Terga II-VII with basal lateral white spots which are turned dorsomesally; terga II-VII all dark dorsally, with basal lateral white spots only, or terga III-V with not very distinct sub-basal pale yellowish spots as well, or terga III-V with distinct sub-basal (sometimes basal on tergum III) median pale spots

as well, or terga III-V with incomplete, or dotted sub-basal pale yellowish bands connected to lateral white spots, or terga III-V with complete or dotted sub-basal transverse pale bands and connected to lateral white spots; tergum VI with lateral white spots only, or with a sub-basal median pale spot and with lateral white spots which are turned dorsomesally, or with a sub-basal transverse complete or dotted pale band and connected to the lateral white spots; segment VIII completely retracted. *Terminalia.* Apical margin of sternum VIII with a deep U-shaped notch at middle and with conspicuous rounded lateral lobes; insula longer than broad, with minute setae and with 6-8 larger setae on apical 0.4; tergum IX with well-developed lateral lobes, each with 3-6 setae; apical margin of postgenital plate with a shallow notch; cerci short and broad; 3 spermathecae, one larger than the other 2.

PUPA. *Cephalothorax.* Trumpet 3.0-4.0 as long as wide at the middle; setae 1,2-C usually single (1,2), 3-C single, 1,3-C longer than 2-C, 4-C usually double (1-3), 5-C usually double (1-4), 6-C single, stout, much stouter than 7-C, 7-C single or double, 8-C with 1-8 branches, 9-C single, 10-C with 1-6 branches, mesad and caudad of 11-C, 11-C single, stout, 12-C with 1-3 branches. *Abdomen.* Seta 1-I well developed, with more than 10 branches, dendritic, 2-I single, 3-I single, long, 2,3-I not widely separated, distance between them same as the distance between 4, 5-I; 1-II with 4-16 branches; 1-III usually double (1-6); 3-II,III single, shorter than segment III; 1-IV single or double; 2-IV,V mesad of 1-IV,V; 5-IV,V single or double; 5-IV-VI usually short, not reaching beyond posterior margin of following segment, or sometimes 5-IV,V long, reaching beyond posterior margin of following segment; 9-I-V small, single, simple; 9-VI,VII usually single, simple or barbed, or sometimes 9-VI,VII double, much stouter and longer than preceding ones; 9-VIII with 2-8 branches, each barbed, or 9-VIII with 2,3 main stems (2-6) and lateral branches of various lengths. *Paddle.* Margins with fringe; apex rounded or produced; seta 1-P single.

LARVA. *Head.* Antenna less than 0.5 length of head, without spicules; seta 1-A inserted near middle of shaft, single; inner mouth brushes pectinate at tip; 4-C well developed, branched, closer to 6-C than 5-C, cephalad and mesad of 6-C, 5-C single, long, 6-C single or double, 7-C with 2-4 branches, 8,9-C single, 10,13-C single or double, 11-C with 2-5 branches, 12-C usually double, 14,15-C with 2,3 branches; mentum with 9-13 teeth on each side. *Thorax.* Setae 1,7-P with 2,3 branches, 2,6,9,11-P single, 3-P double, 4-P usually double (2,3), 5-P single or double, 14-P with 2-4 branches; 5-M usually double, rarely single, 6-M with 3-6 branches, 7-M single, 8-M with 4-7 branches, 9-M with 2-4 branches, 10,12-M single, long, stout, 11-M single, small; 7-T with 4-8 branches, 9-T with 2,3 branches, 10,11-T similar to those on mesothorax, 12-T much reduced. *Abdomen.* Seta 6-I,II with 3-5 branches; 7-I single or double; 7-II with 2,3 branches; 6-III-V usually double (2,3); 6-VI single or double; 1-VII usually 3-branched (2-4), 2-VII single or double; 2-VIII distant from 1-VIII, 2,4-VIII single, 1,3,5-VIII with 3-5 branches; comb of 8-16 scales, in a single row, each scale with fine denticles at the base of the apical spine, sometimes comb scale with apical spine split at tip. Anal segment with saddle complete or incomplete; marginal spicules present; 1-X usually 2-branched (2,3), 2-X with 2-4 branches, 3-X single or double; ventral brush with 4 pairs of setae on grid, 4a,b-X with 1-4 branches, 4c,d-X with 2-4 branches; no precratal tufts; anal papillae 1.5-3.5 length of saddle, the dorsal pair longer than the ventral pair, sausage-like. *Siphon.* Short, about 2.0-2.6 as long as wide, acus absent; pecten teeth 8-20, evenly

spaced, each tooth with 1,2 large and 1,2 small basal denticles; seta 1-S with 2-5 branches, inserted beyond last tooth and beyond the middle of the siphon.

DISTRIBUTION. The *scutellaris* group of Tonga is confined to the Tonga islands and Niue Island, in the South Pacific. It is found from Tafahi Island in the north, to Eua Island in the south, and from Niue Island in the east, to Niuafo'ou Island in the northwestern corner (Map VII).

TAXONOMIC DISCUSSION. At present, the *scutellaris* group comprises 3 species and one subspecies: *cooki* Belkin, *kesseli* n. sp., *tongae tongae* Edwards and *tongae tabu* Ramalingam and Belkin. *Aedes cooki* is found within the Fiji-Tonga-Samoa area while *kesseli, tongae tongae* and *tongae tabu* are restricted to Tonga.

In the identification of the members of the group in Tonga, a combination of male terminalia and larval characters are the most promising. All adults treated in this revision are very similar and those of each taxon are extremely variable, particularly in ornamentation of the abdomen. Consequently, specific and subspecific identification of single specimens is frequently difficult or impossible. The male terminalia of most members are distinct, but the differences between them tend to be very slight and often not of sufficient magnitude to provide definite identification. The same applies to the immature stages so that for an accurate identification or determination of the members of the *scutellaris* group of Tonga, all stages must be examined.

KEYS TO THE SPECIES OF THE *AEDES SCUTELLARIS* GROUP IN FIJI-TONGA-SAMOA

ADULTS (MALES AND FEMALES)

1. Supraalar white line complete, with broad flat scales over wing root; midlobe of scutellum with broad white scales and with dark apical scales (Fig. 23). 2

   Supraalar white line more or less complete, with only narrow scales over wing root; midlobe of scutellum with all broad white scales and without dark apical scales (Fig. 16). . . . . . *futunae* Belkin

2(1). Lower mesepimeral white scale patch absent or very small, with no more than 3 scales. 3

   Lower mesepimeral white scale patch well developed, with more than 3 scales. 5

3(2). Hindtarsomere 4 with basal 0.75 or more white (Fig. 16). *rotumae* Belkin

   Hindtarsomere 4 with basal 0.70 or less white. 4

4(3). Dorsal surface of hindfemur with basal 0.25 or more white (Fig. 16). *kesseli* n. sp. (in part) (p. 23)

   Dorsal surface of hindfemur with basal 0.12 or less white (Fig. 16). *upolensis* Marks

5(2). Lateral prescutal white line present, or at least with some narrow white scales on scutal angle area (Fig. 23). *pseudoscutellaris* (Theobald)

   Lateral prescutal white line not present. 6

6(5). Subspiracular area with scales (Fig. 16). . . . *horrescens* Edwards
Subspiracular area without scales. 7

7(6). Males (See Key to Male Terminalia)
Females. 8

8(7). Dorsal surface of hindfemur with basal area all dark or at most 0.07 white (Fig. 16). . . . . *polynesiensis* Marks
Dorsal surface of hindfemur with basal area 0.10 or more white (Fig. 16). 9

9(8). Lateral white spots on abdominal terga VI, VII extending considerable distance dorsad (best seen from dorsal aspect); abdominal tergum VI usually (80% or more) with a complete or dotted sub-basal transverse pale band and connected to the lateral white spots (Fig. 15). 10
Lateral white spots on abdominal terga VI, VII with only a short dorsal projection (best seen from dorsal aspect); abdominal tergum VI usually (80% or more) without a complete or dotted sub-basal transverse pale band (Fig. 15). 11

10(9). Scutum with a prominent median longitudinal white stripe; abdominal tergal bandings usually curved up, basal at middle and sub-basal on lateral sides; dorsal surface of hindfemur usually with basal at least 0.20 white (Fig. 15). . . . . . *tongae tongae* Edwards (p. 35)
Scutum usually with a rather narrow median longitudinal white stripe; abdominal tergal bandings usually rather narrow and straight, sub-basal at middle and lateral sides; dorsal surface of hindfemur usually with basal at most 0.15 white (Fig. 15).
tongae tabu Ramalingam and Belkin (p. 45)

11(9). Abdominal terga II-VII usually with basal lateral white spots only, or sometimes terga III-V with not very distinct sub-basal pale yellowish spots as well (Fig. 15). . . . . . . *kesseli* n. sp. (in part) (p. 23)
Abdominal terga III-V usually with sub-basal (sometimes basal on tergum III) median pale spots, or sometimes with incomplete or dotted sub-basal pale yellowish bands connected to lateral white spots (Fig. 15). . . . . *cooki* Belkin (p. 10)

MALE TERMINALIA

1. Claspette with modified setae. 2
Claspette without modified setae (best seen from sternal aspect of dissected claspette) (Fig. 21, 23) . . . . . *polynesiensis* Marks

2(1). Claspette distinctly apically expanded (Figs. 17, 19). 3
Claspette slightly apically expanded. 4

3(2). Claspette strongly compressed, with a row of modified setae along apical margin from apicotergal to apicosternal angles in lateral aspect (dissected) (Fig. 19). . . . . *horrescens* Edwards

Claspette with expanded apical portion facing laterad, with numerous setae and with several modified setae on mesal angle of expanded apical portion in lateral aspect (dissected) (Fig. 17).
futunae Belkin

4(2). Claspette short, sternally truncated, with a distinct oval face in sternal aspect (dissected), with numerous setae and with 3-5 spine-like modified setae on mesal side of oval face (Fig. 26).
rotumae Belkin

Claspette rather elongate, apically rounded. 5

5(4). Claspette with poorly developed, slender, apically attenuate or curved modified setae on sternal side in lateral aspect (dissected) (Fig. 28). *upolensis* Marks

Claspette with distinctly flattened, sharply pointed modified setae on sternal side in lateral aspect (dissected). 6

6(5). Lateral surface of claspette with setae extending basad to about 0.5 of the entire claspette length (Fig. 24).
pseudoscutellaris (Theobald)

Lateral surface of claspette with setae extending basad to at most 0.4 of the entire claspette length. 7

7(6). Claspette with 4 or 5 modified setae in a row on apical 0.16-0.20 of sternal side, the modified setae rather slender; without a basosternal angle in lateral aspect (dissected) (Figs. 1, 4). 8

Claspette with 5-7 modified setae in a row on apical 0.20-0.25 of sternal side, the modified setae rather stout and distinct; with a basosternal angle in lateral aspect (dissected) (Figs. 7, 10). . 9

8(7). Tergum IX usually with middle rounded (Fig. 1). . *cooki* Belkin (p. 10)

Tergum IX with middle truncated (Fig. 4). . . . *kesseli* n. sp. (p. 23)

9(7). Lateral surface of claspette with setae extending basad to about level of modified setae, or to 0.33 of the entire claspette length (Fig. 7).
tongae tongae Edwards (p. 35)

Lateral surface of claspette with setae extending basad to 0.28-0.40 of the entire claspette length (Fig. 10).
tongae tabu Ramalingam and Belkin (p. 45)

PUPAE

1. Seta 9-VI much stouter than 9-V, at least 2.0 length of 9-V. . . . 2

Seta 9-VI about as thick as 9-V, less than 2.0 length of 9-V (Fig. 17).
futunae Belkin

2(1). Seta 1-II usually primarily branched. 3

Seta 1-II usually secondarily branched. 4

3(2). Seta 9-VI, VII usually single, simple; 5-IV, V usually single (Figs. 24, 26). . . . . *pseudoscutellaris* (Theobald), *rotumae* Belkin

Seta 9-VI, VII usually double; 5-IV, V usually double (Fig. 19).
horrescens Edwards

4(2). Seta 9-VI, VII usually single, slender and simple (Figs. 4, 28).
upolensis Marks *kesseli* n. sp. (p. 23)
Seta 9-VI, VII usually single, stout and barbed or forked at tip. . . 5

5(4). Seta 5-IV, V usually single (Figs. 7, 10, 21). . *polynesiensis* Marks
tongae tongae Edwards (p. 35)
tongae tabu Ramalingam and Belkin (p. 45)
Seta 5-IV, V usually double (Fig. 1). . . . . *cooki* Belkin (p. 10)

FOURTH STAGE LARVAE

1. Saddle complete. 2
Saddle incomplete. 8

2(1). Seta 5-M single. 3
Seta 5-M double. 6

3(2). Seta 4a, b-X single (Fig. 25). . . . . . *pseudoscutellaris* (Theobald)
Seta 4a, b-X branched. 4

4(3). Comb scale with fine denticles or fringes at base of apical spine
(Fig. 22). *polynesiensis* Marks
Comb scale with coarser denticles at base of apical spine. 5

5(4). Pecten tooth with very strong basal anterior denticles (Fig. 20)
horrescens Edwards
Pecten tooth with rather small basal anterior denticles (Fig. 27)
rotumae Belkin

6(2). Setae 4a, b-X usually single or double. 7
Setae 4a, b-X usually with 3 branches (2-4) (Fig. 2).
cooki Belkin (p. 10)

7(6). Setae 4a, b-X usually single (1, 2) (Fig. 11).
tongae tabu Ramalingam and Belkin (p. 45)
Setae 4a, b-X usually double (1, 2) (Fig. 8)
tongae tongae Edwards (p. 35)

8(1). Seta 5-M single. . . . . Wallis form*
Seta 5-M double. 9

9(8). Pecten tooth with broad main shaft and apically frayed (Fig. 18).
futunae Belkin
Pecten tooth with very slender main shaft and apically pointed. . . 10

10(9). Seta 13-P present (Fig. 29). . . . . *upolensis* Marks
Seta 13-P absent (Fig. 5). . . . . *kesseli* n. sp. (p. 23)

*See Belkin 1962: 480.

DESCRIPTIONS, BIONOMICS AND MEDICAL IMPORTANCE OF THE SPECIES OCCURRING IN TONGA

AEDES (STEGOMYIA) COOKI BELKIN
(Figs. 1, 2, 3, 13, 14, 15, 16)

Aedes (Stegomyia) cooki Belkin 1962: 454 (♂*, ♀, P*, L*).

MALE. *Head.* Proboscis dark scaled, with some pale scales on the ventral side (proboscis in Niuafo'ou specimens sometimes without such scales), longer than forefemur; palpus 5-segmented, dark, shorter than proboscis, with a white basal band on each of segments 2-5; those on segments 4, 5 dorsally incomplete; segments 4, 5 subequal, slender, upturned, and with only a few short setae; antenna plumose, shorter than proboscis; torus covered with white scales except on dorsal side; clypeus bare; decumbent scales of vertex all broad and flat; erect forked scales dark, not numerous, restricted to occiput; vertex with a median stripe of broad white scales, with broad dark ones on each side interrupted by a lateral stripe of broad white scales followed ventrally by a patch of broad white scales. *Thorax.* Scutum with narrow dark scales and a distinct median longitudinal stripe of similar white scales, median stripe from anterior margin, narrows slightly posteriorly and reaches to the beginning of the prescutellar space; prescutellar line with a few narrow pale yellowish scales (Niuafo'ou specimens usually lack prescutellar line); posterior dorsocentral line developed, with some narrow pale yellowish scales; supraalar line of broad white scales; acrostichal bristles absent; dorsocentral bristles present; scutellum with broad white scales on all lobes and with a few broad dark scales at apex of midlobe; anterior pronotum with broad white scales; posterior pronotum with narrow dark scales on upper portion and with broad white scales on lower portion forming a white stripe instead of a white patch; paratergite with broad white scales; postspiracular area without scales; subspiracular area without scales; patches of broad white scales on propleuron, on the upper and lower portions of sternopleuron and on the upper and lower portions of mesepimeron; upper sternopleural scale patch reaches to anterior corner of sternopleuron; lower mesepimeral scale patch small, or medium sized (Niuafo'ou specimens lower mesepimeral scale patch usually small) and separated from upper mesepimeral scale patch, or sometimes narrowly connected; lower mesepimeron without setae; metameron bare. *Wing.* With dark scales on all veins except for a minute basal spot of white scales on costa; cell R_2 about 1.5 length of R_{2+3}. *Halter.* With dark scales. *Legs* (Fig. 16). Coxae with patches of white scales; knee spots present on all femora; fore- and midfemora anteriorly dark; hindfemur anteriorly with a broad white longitudinal stripe which widens at basal 0.33-0.50 and is separated from apical white scale patch; all tibiae anteriorly dark; fore- and midtarsi with basal white bands on tarsomeres 1, 2 (Niuafo'ou and Niue specimens sometimes have fore- and midtarsi with basal white bands only on tarsomere 1); hindtarsus with basal white bands on tarsomeres 1-4, the ratio of length of white band to the total length of tarsomere is 0.33, 0.33, 0.40 and 0.50-0.60; tarsomere 5 entirely white, or sometimes with a few dark scales at tip on ventral side; sometimes hindtarsus with basal white band on tarsomere 4 interrupted by a few dark scales on ventral side as well (Niuafo'ou specimens), or basal white bands on tarsomeres 4, 5 interrupted by a stripe of dark scales on ventral side (Vava'u and Niue specimens); sometimes hindtarsus with basal white bands on tarsomeres 2-5 interrupted by a stripe of dark scales on ventral side (Nieu specimens); fore- and midlegs

with tarsal claws unequal, the larger one toothed, the smaller one simple; hindleg with tarsal claws equal, simple. *Abdomen* (Fig. 14). Segment I with white scales on laterotergite, rarely with a large median pale spot as well; tergum II with basolateral white spots only, or sometimes with a basal median spot as well; terga III-VI each with a complete or incomplete sub-basal white or pale yellowish band and with lateral white spots which are turned dorsomesally and connected to sub-basal white or pale yellowish bands; sometimes tergum VI with a sub-basal median pale spot and with lateral white spots which are turned dorsomesally; tergum VII with lateral white spots which are turned dorsomesally; tergum VII with lateral white spots only or sometimes with a small subbasal median spot as well; sternum VIII largely covered with white scales. *Terminalia* (Figs. 1, 13). Basimere 3.8 as long as wide, scales restricted to dorsolateral, lateral and ventral areas, with a patch of setae on the basomesal area of dorsal surface, mesal surface membranous; claspette simple, slender, sternal and tergal sides parallel, apically rounded, with 4 or 5 modified setae in a row on apical 0.16-0.20 of sternal side, lateral surface with fine setae extending basad to about level of modified setae, or to 0.25 of the entire claspette length, apex tergally with setae about 0.5 length of entire claspette length; distimere simple, elongate, length of basimere, slightly swollen near tip, with a spiniform process and a few setae near apex; aedeagus with a distinct sclerotized lateral toothed plate on each side; paraproct without teeth; cercal setae absent; apical margin of tergum IX with middle rounded and with a hairy lobe on each side.

FEMALE. Essentially as in the male, differing in the following respects: *Head*. Palpus 4-segmented, about 0.2 length of proboscis, with white scales on apical half or less. *Wing*. With cell R_2 about 2.0 length of R_{2+3}. *Legs*. Fore- and midlegs with tarsal claws equal, simple. *Abdomen* (Fig. 15). Tergum I sometimes with a large median pale spot as well; terga II-VII with basal lateral white spots which are dorsomesally turned; terga III-V usually with subbasal (sometimes basal on tergum III) median pale spots as well, or sometimes terga III-V with incomplete or dotted subbasal pale yellowish bands connected to lateral white spots, rarely terga III-V with complete subbasal pale yellowish bands connected to lateral white spots; sometimes terga II-VII dorsally dark; segment VIII completely retracted. *Terminalia* (Fig. 3). Apical margin of sternum VIII with a deep U-shaped notch at middle and with conspicuous rounded lateral lobes; insula longer than broad, with minute setae and with 6 or 7 larger ones on apical 0.4; apical margin of tergum IX with well-developed lateral lobes, each with 4 (3-5) setae; apical margin of postgenital plate with a shallow notch; cerci short and broad; 3 spermathecae, one larger than the other 2.

PUPA (Fig. 1). *Cephalothorax*. Trumpet about 4.0 as long as wide at the middle; setae 1,2,7-C usually single (1,2), 3-C single; 1,3-C longer than 2-C, 4-C usually double (1-3), 5-C usually double (1-4), 6-C single, stout, much stouter than 7-C, 8-C usually with 3,4 branches, 9-C single, long, 10-C usually double (1-5), mesad and caudad of 11-C, 11-C single, stout, 12-C usually single (1-3). *Abdomen*. Seta 1-I well developed, with more than 10 branches, dendritic; 2-I single, 3-I single, long, 2,3-I not widely separated, distance between them same as the distance between 4,5-I; 1-II with 6-13 branches; 1-III usually double (1-3); 3-II, III single, shorter than segment III; 1-IV usually double (1,2); 2-IV, V mesad of 1-IV, V; 5-IV, V usually double, or sometimes 5-IV-VI single; 5-IV-VI short, not reaching beyond posterior margin of following segment; 9-I-V small, single, simple; 9-VI, VII usually single, stout and barbed, or sometimes 9-VII double, much stouter and longer than preceding ones; 9-VIII with 2-5 branches, each barbed. *Paddle*. Margins with fringe;

seta 1-P single.

LARVA (Fig. 2). *Head.* Antenna less than 0.5 length of head, without spicules; seta 1-A inserted near middle of shaft, single; inner mouth brushes pectinate at tip; 4-C well developed, branched, closer to 6-C than to 5-C, cephalad and mesad of 6-C, 5-C single, long, 6-C usually double (1,2), 7-C usually 3-branched, 8-10,13-C single, 11-C usually with 2-5 branches, 12-C usually double, 14,15-C usually with 2,3 branches; mentum with 9,10 teeth on each side. *Thorax.* Seta 1-P usually 3-branched, 2,6,9,11-P single, 3,4-P double, 5-P usually single (1,2), 7-P usually double (2,3), 14-P usually double (2,3); 5-M usually double, rarely single, 6-M with 3,4 branches, 7-M single, 8-M usually with 4-6 branches, 9-M usually 3-branched (3,4), 10,12-M single, long, stout, 11-M single, small; 7-T usually with 5,6 branches, 9-T usually double (2,3), 10,11-T similar to those on mesothorax, 12-T much reduced. *Abdomen.* Seta 6-I usually 3-branched (3-5), 7-I usually single (1,2); 6-II usually 3-branched (3,4), 7-II usually 3-branched (2,3); 6-III-V usually double (2,3); 6-VI usually double (1,2); 1-VII usually 3-branched (3,4), 2-VII usually double (1,2); 1-VIII usually with 3,4 branches, 2-VIII distant from 1-VIII, 2,4-VIII single, 3-VIII usually 4-branched (3-5), 5-VIII usually with 4,5 branches; comb of 9-15 scales, in a single row, each scale with fine denticles at the base of the apical spine, sometimes comb scale with apical spine split at tip; anal segment with saddle complete; marginal spicules present; 1-X usually 2-branched (2,3); 2-X usually with 3,4 branches, sometimes 2-branched; 3-X usually double (1,2); ventral brush with 4 pairs of setae on grid, each seta usually 3-branched (3,4), rarely 2-branched; no precratal tufts; anal papillae 1.5-2.0 length of saddle, the dorsal pair longer than the ventral pair, sausage-like. *Siphon.* Short, about 2.3 as long as wide, acus absent; pecten teeth 10-19, evenly spaced, each tooth usually with 1 large and 1,2 small basal denticles; seta 1-S with 3,4 branches, inserted beyond last tooth and beyond the middle of the siphon.

TYPE-DATA. *Aedes (Stegomyia) cooki* Belkin, holotype male with associated terminalia slide (580704-23), in BMNH; type-locality: Niue Island, IX-1957 (M. O. T. Iyengar). Allotype female, with same data as holotype, except from cistern, collected in X-1957, in BMNH. Paratypes: 13 females, 5 larvae, with same data as allotype; 1 male with associated terminalia slide (580714-7), same data as holotype, collected IX-20-1957; 1 male with associated terminalia slide (580714-1), same data as holotype, collected IX-21-1957; 3 pupae, with same data as holotype, except from coconut shells, collected IV-10-1958.

DISTRIBUTION. This species is known from Niue Island and Tonga. In Tonga, we report it for the first time from Niuafo'ou Island and the Vava'u Group (Maps III, IV).

2,659 specimens examined: 526♂, 525♀, 146♂ terminalia, 5♀ terminalia, 650 L, 105 l, 54 p, 328 individual rearings (320 l, 328 p).

NIUE ISLAND. (IX-X-1957, M. O. T. Iyengar), 3♂, 14♀, 3♂ terminalia, 5 L; (IV-1958, M. O. T. Iyengar), 3 p; (V-VI-1973 progeny rearings in USMN), 78♂, 66♀, 39♂ terminalia, 5♀ terminalia, 28 L, 145 individual rearings (144 l, 145 p); (VII-1973 individual rearings), 179♂, 169♀, 10♂ terminalia, 434 L, 7 l, 35 p.

TONGA. *Niuafo'ou Island.* (XI-1972-I-1973 progeny rearings in USNM), 14♂, 15♀, 11♂ terminalia, 14 L, 31 individual rearings (31 l, 31 p); (1970, individual rearings), 4♂, 3♀, 1♂ terminalia; (1972 Coll. 70-71), 118♂, 132♀, 27♂ terminalia, 98 l, 16 p, 40 individual rearings (33 l, 40 p); *Vava'u Group,* (VII-1975 progeny rearings in USNM), 24♂, 34♀, 20♂ terminalia, 2 L, 59 in-

dividual rearings (59 l, 59 p); (1975, individual rearings), 106♂, 92♀, 35♂ terminalia, 167 L, 53 individual rearings (53 l, 53 p).

TAXONOMIC DISCUSSION. This species has been confused in the past with *tongae*, which is apparently restricted to the Ha'apai Group. Although *cooki* closely resembles *tongae*, it is definitely a distinct species and its male terminalia especially are different from those of *tongae*. The 2 species can be fairly readily differentiated in all stages by the characters given in the keys.

Aedes cooki is an extremely variable species. Its affinities appear to be with *tongae* and *polynesiensis*, but the male terminalia most closely resemble those of *kesseli*, a new species from the Niuatoputapu Group.

The ornamentation of the adults of *cooki* is somewhat intermediate between *polynesiensis* and *tongae*. The pupa is extremely similar to those of *polynesiensis* and *tongae* in seta 9-VI, VII usually single, stout, and barbed, or forked at tip. It can be distinguished from those of *polynesiensis* and *tongae* by seta 5-IV, V which is usually double. The larva is very similar to that of *polynesiensis* but can easily be distinguished from that of *polynesiensis* by the branched condition of seta 5-M. It is also very similar to that of *tongae* but can be distinguished from *tongae* by setae 4a, b-X which are usually 3-branched (2-4). In *tongae*, setae 4a, b-X are usually double (1, 2).

At present, *cooki* is the only known species of the *scutellaris* group on Niue, Niuafo'ou, and the Vava'u Group, in the South Pacific.

BIONOMICS. *Aedes cooki* is well established within its range and is a common man-biter. The immatures occur in all types of natural and man made habitats. It is the commonest mosquito found throughout its range and its first batch of eggs can develop autogenously. *Aedes cooki* is an important vector of filariasis and has been found naturally infected with *Wuchereria bancrofti* and *Dirofilaria immitis* Leidy. It is suspected to have been the major vector of dengue-2 on Niue Island and is a suspect vector of dengue-1 in the Vava'u group. Field studies were made on Niue Island from 18 April to 23 May 1973 and in the Vava'u group of Tonga from 12 June to 1 July 1975. Only incidental collections were made on Niuafo'ou Island on 29 April 1968, 24 September 1970 and 14 October 1972 during a brief trip ashore, with the main emphasis on obtaining biting-landing mosquitoes for colony development.

Immature habitats. One hundred and sixty potential mosquito immature habitats were surveyed for *cooki* (Niue Island (83), the Vava'u Group (70) in Tonga, and Niuafo'ou Island (7) in northern Tonga (see Maps VII and VIII)). One hundred and thirty-nine samples were positive for mosquitoes of which 117 were positive for *cooki* as shown in Table 1. The 21 sites negative for mosquito larvae were mainly large artifical containers (including 14/24 cisterns). The 3 coral rock holes were on Niue and included one coastal rock hole and 2 on the terrace between 24 and 61 m above sea level. Sixteen of the leaf axil collections positive for *cooki* were on Niue where there is no competition for this niche by *Ae. oceanicus* Belkin or any other member of the *Ae. (Finlaya)* group*. On Vava'u, *cooki* was collected in association with *oceanicus* on one occasion from *Pandanus*, while only *oceanicus* was recovered from the remaining 14 leaf axil collections made in Vava'u. Among the natural immature habitats sampled (excluding artificial containers) only 4.2% were negative for mosquitoes, and 80.2% were found with *cooki*; while 26.6% of the artificial

*The only other species that occur on Niue are *Ae. aegypti* (Linnaeus), *Culex quinquefasciatus* Say and *Cx. sitiens* Wiedemann.

containers were negative for mosquitoes, with 62.5% positive for *cooki*. It is interesting that on Niue Island only 7.2% of the sampled sites were negative, while 90.4% were positive for *cooki* as compared to 19.5% and 54.5% in Vav'u and Niuafo'ou. This noticeable difference was due to 2 major factors. First, the full scale utilization of the leaf axil niche on Niue by *cooki* in the absence of other leaf axil breeders, i.e., 88.9% positive; compared to Vavu'u where *cooki* was competing with *oceanicus* for the niche, 100% of the leaf axil collections were positive for *oceanicus* while only 1(6.7%) provided *cooki* which was in association with *oceanicus*. Second, the relatively sterile nature of large artificial containers used for water storage (cisterns) where 14 of 19 (73.7%) were negative for mosquitoes in Vava'u, whereas 5 of 5 sampled on Niue were positive for *cooki*. Both Niue Island and the Vava'u group are short of water and of necessity employ the use of cistern and large water storage containers, which besides providing breeding place for *cooki*, also provide larval habitats for the 2 introduced domestic mosquitoes, *Culex quinquefasciatus* and *Ae. aegypti*.

Relative abundance of cooki *in aquatic habitats*. Even though only subsamples are taken from any aquatic sites and usually more than one leaf axil is sampled in a single collection, the relative abundance among similar sites, as well as cross category estimates, can be made by establishing some rather arbitrary levels derived from the number of immatures sampled per collection.* It was observed that 53.0% of the samples of *cooki* were considered abundant, 17.9% common and 29.1% few (Table 1).

Among the natural larval habitats it was 58.4%, 19.5% and 22.1% respectively. Sixty per cent of the tree holes were considered abundant habitats with all 10 of the larger tree holes and 38.9% of the smaller tree holes in the abundant range. Coconuts represent a niche in which total counts of immatures can be obtained. This numerous and prolific niche provided abundant counts in 74.1% of the samples, with actual counts as high as 393 healthy immature *cooki* from a drinking nut from Pangai Motu, an island in the Vava'u group. The highest count on Niue Island was a split coconut with 142 immatures. Only 35.3% of the leaf axil collections provided abundant counts. These were all from giant talo (kape), *Alocasia macrorrhiza* (Linnaeus) which has larger accumulations of water than in either talo, *Colocasia esculenta* (Linnaeus), or *Pandanus* sp. Artificial containers provided 42.5% abundant, 15.0% common and 42.5% few for *cooki* immatures. However, if we look at the smaller containers which more closely resemble natural immature sites we find that 66.7% were abundant and only 16.7% few. This compares with 32.1% abundant and 53.6% few for the larger containers.

Immature habitat preference. The 3 major natural habitats for immature *cooki* are tree holes, coconuts (either drinking, rat-eaten or split) and leaf axils. The order of relative importance of these sites appears to differ in each of the areas. On Niue, it is leaf axil - tree hole - coconut, while on Vava'u, it is coconut - tree hole - leaf axil. Although few collections have been made on the isolated volcanic island of Niuafo'ou, the order of importance would probably be tree hole - coconut - leaf axil. The order of preference depends upon the numbers of available sites in the area as well as the possible interspecific competition that is most likely responsible for the full exploitation of the leaf axil niche in Niue. Coral rock holes are abundant on Niue and when

*Abundant = 20+; common = 10-19; few = 1-9 immatures per sample.

TABLE 1. Immature habitats sampled and the relative abundance of *Aedes cooki* by category.

Immature habitat category	Niue						Vava'u						Total					
	Number collected	Negative for mosquitoes	Positive for *Ae. cooki*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. cooki*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. cooki*	A	C	F
Rock hole	3	-	3	2	-	1	2*	-	0	-	-	-	5	-	3	2	-	1
(Coral)	(3)	(-)	(3)	(2)	(-)	(1)	(0)	(-)	(-)	(-)	(-)	(-)	(3)	(-)	(3)	(2)	(-)	(1)
(Volcanic)	(0)	(-)	(-)	(-)	(-)	(-)	(2)*	(-)	(0)	(-)	(-)	(-)	(2)	(-)	(0)	(-)	(-)	(-)
Tree hole	14	-	14	10	3	1	14*	-	14	7	3	4	28	-	28	17	6	5
(Small)	(10)	(-)	(10)	(6)	(3)	(1)	(8)*	(-)	(8)	(1)	(3)	(4)	(18)	(-)	(18)	(7)	(6)	(5)
(Large)	(4)	(-)	(4)	(4)	(-)	(-)	(6)	(-)	(6)	(6)	(-)	(-)	(10)	(-)	(10)	(10)	(-)	(-)
Fallen frond	1	-	1	-	-	1	0	-	-	-	-	-	1	-	1	-	-	1
Coconut	11	1	10	7	1	2	19	1	18	13	3	2	30	2	28	20	4	4
Leaf axil	18	2	16	6	4	6	15	-	1	-	1	-	32	2	17	6	5	6
(Giant talo)	(12)	(-)	(12)	(6)	(3)	(3)	(3)	(-)	(0)	(-)	(-)	(-)	(15)	(-)	(12)	(6)	(3)	(3)
(Talo)	(5)	(1)	(4)	(-)	(1)	(3)	(6)	(-)	(0)	(-)	(-)	(-)	(11)	(1)	(4)	(-)	(1)	(3)
(Pandanus)	(0)	(-)	(-)	(-)	(-)	(-)	(4)	(-)	(1)	(-)	(1)	(-)	(4)	(-)	(1)	(-)	(1)	(-)
(Pineapple)	(0)	(-)	(-)	(-)	(-)	(-)	(1)	(-)	(0)	(-)	(-)	(-)	(1)	(-)	(0)	(-)	(-)	(-)
(Compass palm)	(1)	(1)	(0)	(-)	(-)	(-)	(0)	(-)	(-)	(-)	(-)	(-)	(1)	(1)	(0)	(-)	(-)	(-)
Subtotal natural sites	46	3	44	25	8	11	50	1	33	20	7	6	96	4	77	45	15	17
Artificial container	37	3	31	14	6	11	27	14	9	3	-	6	64	17	40	17	6	17
(Small)	(9)	(-)	(9)	(6)	(2)	(1)	(3)	(-)	(3)	(2)	(-)	(1)	(12)	(-)	(12)	(8)	(2)	(2)
(Large)	(28)	(3)	(22)	(8)	(4)	(10)	(24)	(14)	(6)	(1)	(-)	(5)	(42)	(17)	(28)	(9)	(4)	(15)
Total	83	6	75	39	14	22	77	15	42	23	7	12	160	21	117	62	21	34

*Include 5 tree hole collections (small) and 2 rock hole collections (volcanic) from Niuafo'ou Island.
A = abundant, 20+; C = common, 10-19; F = few, 1-9 immatures per sample.

they hold water (many are permeable), they are effectively utilized by *cooki*. No coral rock holes were observed in Vava'u. Volcanic rock holes are common on Niuafo'ou and probably provide excellent conditions for *cooki* as they do for *kesseli* on Tafahi, however, the only 2 sampled were splashed by waves with consequent high salinity and occurrence of *Cx. sitiens*. Because of the shortage of water on these islands, there are many water storage containers which provide easily accessible peridomestic habitats for the ubiquitous *cooki*. In Vava'u, the large concrete cisterns appear to be less attractive to *cooki* than other man-made sites and parallels that observed for *tongae tabu* on Tongatapu.

Mosquito species composition at larval habitats. In its range, *cooki* was found with 4 other species: *Ae. aegypti, Ae. oceanicus, Cx. quinquefasciatus* and *Cx. sitiens*. Table 2 summarizes the associations and gives the species composition of all immature collections. Of 139 collections positive for Culicidae: 115 contained *cooki*, 23 *aegypti*, 15 *oceanicus*, 14 *quinquefasciatus* and 8 *sitiens*. *Aedes cooki* dominated all larval habitats with the exception of those too foul. It occurred in 82.7% of the habitats, with 63.3% containing *cooki* alone. On Niue Island where it is obvous that both *aegypti* and *Cx. quinquefasciatus* are recent immigrants, the latter being the most recent, *cooki* was recovered in 96.1% of all collections in a wide variety of habitats, and as the only species in 71.1%. For Vava'u, the figures were similar if the 15 leaf axil collections, in which *oceanicus* was omnipresent were extracted, giving 87.8% and 70.7% respectively; showing that *aegypti* and *Cx. quinquefasciatus* are also not so well established in the Vava'u group. In both areas, many habitats were sampled in peridomestic situations, including numerous artificial containers. Only 21 collections positive for Culicidae did not contain *cooki*, including: 14 leaf axil collections in Vava'u, all positive for *oceanicus*

TABLE 2. Mosquito species composition at larval habitats.

Species	Total	Niue	Vava'u	Niuafo'ou
(No mosquitoes found)	(21)	(6)	(15)	(0)
Ae. cooki only	88	54	29	5
Ae. cooki with *Ae. aegypti*	13	12	1	0
Ae. cooki, Ae. aegypti and *Cx. quinquefasciatus*	4	1	3	0
Ae. cooki, Ae. aegypti and *Cx. sitiens*	4	4	0	0
Ae. cooki with *Cx. quinquefasciatus*	3	0	3	0
Ae. cooki with *Cx. sitiens*	2	2	0	0
Ae. cooki with *Ae. oceanicus*	1	0	1	0
Ae. aegypti with *Cx. quinquefasciatus*	1	0	1	0
Ae. aegypti only	1	0	1	0
Cx. quinquefasciatus only	6	3	3	0
Cx. sitiens only	2	0	0	2
Ae. oceanicus only	14	0	14	0
Total	139	76	56	7

only; 2 collections from volcanic rock holes on Miuafo'ou contained only *Cx. sitiens;* while the remaining 7 were in artificial containers: 3 (2 water troughs and a grease trap) on Niue with *Cx. quinquefasciatus* only; and 4 on Vava'u, 2 with *Cx. quinquefasciatus* (cistern and drum), one cistern with *aegypti* and one cistern with both. *Aedes cooki* was found with other species in only 4 natural sites, i. e. with *Cx. sitiens* in a coconut fragment (Niue), with *aegypti* and *Cx. quinquefasciatus* in a drinking coconut (Vava'u), with *Cx. quinquefasciatus* in a split coconut (Vava'u), and with *oceanicus* in a *Pandanus* leaf axil collection (Vava'u) and 18 artificial container sites. Since artificial containers are so diverse in character, and since they are the major habitat where an association of species occurs, the composition of species in the various artificial container habitats has been subdivided in Table 3. Forty-seven (73.4%) of the artificial containers sampled were positive for Culicidae of which 85.1% had *cooki*, with 21 associated with other species. Only 4 of the 21 associations occurred in Vava'u, i. e., a drum with *aegypti*; a double sink with *aegypti* and *Cx. quinquefasciatus* and a pot and a wooden bowl with *Cx. quinquefasciatus;* the other 17 associations occurred on Niue and can be derived from Table 3.

Invertebrate fauna found associated with mosquito larval habitats. Of the 160 collections, 90.6% provided samples of various invertebrates including: 86.9% positive for Culicidae and 73.1% for *cooki*. Eighty samples (50%) contained species of invertebrates other than mosquitoes, and with the exception of 6 collections, in which only non-culicid invertebrates were found, the remainder were associated with mosquitoes. Table 4 shows the invertebrate fauna associated with specific larval habitats. The coconut niche provided the greatest diversity of invertebrate taxa as well as numbers. It included all of the phyla recorded as well as all the families of Diptera. The coconut niche also provided the greatest variety for single collections. On Niue, from a fragment of coconut shell, 6 taxa were found: 3 *cooki*, 2 *Cx. sitiens*, Ceratopogonidae, a snail, Platyhelminthes and Rotifera. Another 4 collections, (2 Niue, 2 Vava'u) provided 5 associations, for example, 2 from Vava'u contained: 1) a split coconut - 30 *cooki*, 30 Cecidomyiidae, 25 surface mites, 11 cyclorrhaphous Diptera larvae, and one Staphylinidae, and, 2) a drinking coconut - 393 *cooki*, Ceratopogonidae, Psychodidae, cyclorrhaphous larvae and surface mites. A coral rock hole 12.7 x 6.0 x 1.9 cm deep, situated 0.76 m above the ground also contained 6 taxa: 42 *cooki*, Ceratopogonidae, an undetermined orthorrhaphous larva, cyclorrhaphous larvae, Platyhelminthes and surface mites. The coconut niche was followed by the diverse habitats offered by artificial containers and surprisingly, leaf axils. For non-culicid Diptera, the coconut niche was the most prolific, followed by tree holes and leaf axils. Next to Culicidae and other Diptera, the most ubiquitous invertebrate associate was a minute milky white platyhelminth. By far the most significant forms obtained in larval habitats were the Diptera which were recorded in all 145 sites that were positive for invertebrates. Even excluding the target group, Culicidae, the order was the most obvious faunal group present with 40.6% of all site collections sampled and 81.3% of the non-culicid samples. Table 4 also subdivides the Diptera.

Among the non-arthropods, Platyhelminthes (Turbellaria) were sampled on 13 occasions in a variety of sites and included a single specimen of a relatively large terrestrial Tricladida from a split coconut on Niue, while all other samples from Niue and Vava'u contained minute milky white forms, probably members of the genus *Dendrocoelum*. The Aschelminthes, class Rotifera, often overlooked because of their size, were nonetheless recorded on 9 occasions. The Mollusca, class Gastropoda, were all small snails, both discoidal

TABLE 3. Mosquito species composition by type of artificial container.

Artificial container	Number collected	Negative for mosquitoes	Positive for *Ae. cooki*	*Ae. cooki* only	*Ae. cooki* & *Ae. aegypti*	*Ae. cooki, Ae. aegypti* & *Cx. quinquefasciatus*	*Ae. cooki, Ae. aegypti* & *Cx. sitiens*	*Ae. cooki* & *Cx. quinquefasciatus*	*Ae. cooki* & *Cx. sitiens*	*Ae. aegypti* & *Cx. quinquefasciatus*	*Ae. aegypti* only	*Cx. quinquefasciatus* only
Cistern	24	14	7	4	3	-	-	-	-	1	1	1
Canoe	4	0	4	2	1	-	1	-	-	-	-	-
Drum	8	0	7	4	3	-	-	-	-	-	-	1
Tire	6	0	6	3	-	-	3	-	-	-	-	-
Tin	7	1	6	4	2	-	-	-	-	-	-	-
Concrete miscellaneous*	6	1	2	0	-	1	-	-	1	-	-	3
Miscellaneous**	9	1	8	2	3	1	-	2	-	-	-	-
Total	64	17	40	19	12	2	4	2	1	1	1	5

*1) Foundation - negative; 2) lubrication pit - *Ae. cooki, Ae. aegypti* and *Cx. quinquefasciatus;* 3) drain - *Ae. cooki* and *Cx. sitiens;* 4) grease trap, and 5 + 6) water troughs - *Cx. quinquefasciatus* only.

**1) Roof gutter - negative; 2) wheel drum and 3) bottle - *Ae. cooki* only; 4) tub, 5) flower pot, and 6) 5 gallon drum - *Ae. cooki* and *Ae. aegypti;* 7) double sink - *Ae. cooki, Ae. aegypti* and *Cx. quinquefasciatus;* and 8) cooking pot; 9) wooden bowl - *Ae. cooki* and *Cx. quinquefasciatus.*

TABLE 4. Invertebrate fauna associated with mosquito larval habitats.

Taxa	Rock hole (volcanic)	Rock hole (coral)	Artificial containers	Tree hole (large)	Tree hole (small)	Fallen frond	Coconut	Leaf axil (*Pandanus*)	Leaf axil (kape)	Leaf axil (talo)	Leaf axil (pineapple)	Leaf axil (compass palm)	Total leaf axil	Total
Number of collections	2	3	64	10	18	1	30	4	15	11	1	1	(32)	160
(With associated invertebrates)	(2)	(3)	(51)	(10)	(18)	(1)	(29)	(4)	(15)	(10)	(1)	(1)	(31)	145
With associated invertebrates, non-Culicidae	2	3	20	4	13	1	22	2	8	3	1	1	(15)	80
Platyhelminthes	-	2	2	-	1	-	4	-	4	-	-	-	(4)	13
Aschelminthes	-	-	2	-	2	-	1	-	4	-	-	-	(4)	9
Mollusca	-	-	1	-	-	-	5	-	2	1	-	-	(3)	9
Annelida	-	-	-	-	-	-	1	-	-	1	-	-	(1)	2
Arthropoda														
Arachnida	-	1	1	-	-	-	4	-	-	-	-	-	-	6
Diplopoda	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Insecta														
Collembola	-	-	4	-	-	-	5	-	-	-	-	-	-	9
Odonata	-	-	2	-	-	-	-	-	-	-	-	-	-	2
Coleoptera	-	-	-	-	-	-	3	-	-	-	-	-	-	3
Diptera	2	3	51	10	18	1	29	4	15	10	1	1	(31)	145
(Diptera, excluding Culicidae)	(2)	(3)	(15)	(3)	(11)	(1)	(20)	(2)	(5)	(1)	(1)	(1)	(10)	(65)
Diptera subdivisions														
Psychodidae	-	-	-	1	1	-	5	-	1	-	-	-	(1)	8
Chironomidae	-	-	6	1	4	-	2	1	1	-	1	-	(3)	16
Ceratopogonidae	2	3	5	2	8	-	5	1	1	-	-	1	(3)	28
Culicidae	2	3	47	10	18	1	28	4	15	10	1	-	(30)	139
Cecidomyiidae	-	-	-	-	-	1	7	-	-	-	-	-	(0)	8
Orthorrhapha (undetermined)	-	1	-	-	-	-	-	-	-	-	-	-	(0)	1
Cyclorrhapha (undetermined)	-	1	1	-	-	-	11	-	2	1	-	-	(3)	16

and conical. The 2 samples of Annelida, both from Vava'u, included 2 Oligochaeta from the leaf axils of talo and unexpectedly, a Hirudinea from a drinking coconut. The non-dipterous arthropods included: surface mites (Acarina), 2 millipedes in a tree hole at base of a flamboyant (*Delonix regia* (Bojer)), Collembola (both Arthropoleona and Symphypleona) were collected from 3 tires, a cistern and 5 coconuts, but, like surface mites, they are easily missed by the usual mosquito sampling methods and are undoubtedly more common than the records indicate. Anisoptera naiads were observed in a water trough and cistern; while Coleoptera (Staphylinidae and Curculionidae) were found in coconuts.

Non-culicid Diptera associated with cooki. Ceratopogonidae were the most numerous and diverse taxa recovered on Niue and Vava'u and the only associated family recorded in the few samples from Niuafo'ou. This family was represented in 17.5% of all samples and 35% of all non-culicid invertebrate collections. However, there were 2 species involved. On Niue, *Dasyhelea carolinensis* Tokunaga was the only species present (15 collections) and the only species recovered from artificial containers and coral rock holes; it also was in small tree holes, coconuts and leaf axils. In Vava'u, only *Dasyhelea hitchcocki* Wirth was found in small and large tree holes, coconuts and leaf axils of *Pandanus*, but did not occur in artificial containers. Interestingly, on Niuafo'ou both species were recovered, *D. carolinensis* in volcanic rock holes and *D. hitchcocki* in small tree holes (2). The niches utilized by these *Dasyhelea* are the same as those utilized by *cooki*. With the exception of 2 volcanic rock holes on Niuafo'ou where it was associated with *Cx. sitiens* and 3 samples where *D. carolinensis* was the only invertebrate in a foundation, roof gutter and leaf axil of the compass palm, it was always associated with *cooki*.

Chironomidae were in 21.2% of the non-culicid samples, on Niue, but were found on only 3 occasions in Vava'u, i.e. in a cistern and the leaf axils of *Pandanus* and pineapple (*Ananas* sp.) (the 2 leaf axil samples were from the subfamily Orthocladiinae while the cistern and all collections on Niue provided *Chironomus* sp.). The artificial containers positive for *Chironomus* sp. on Niue were a canoe, a petrol drum and 4 of 6 tires sampled. Except for the cistern on Vava'u, where it was the only invertebrate recorded, *Chironomus* sp. was always collected with *cooki*.

Psychodidae, probably *Telmatoscopus vitiensis* Satchell, were recovered only from a leaf axil of kape on Niue, all others were from Vava'u. The Psychodidae were usually found in the more turbid and foul habitats, even so, all of our samples were associated with *cooki*.

Cecidomyiidae of the genus *Resseliella* were found only in coconut shells, often in large numbers (30 or more). The only exception, in numerous collections of these forms in the Fiji - Tonga - Samoa area was in the base of a fallen coconut frond on Niue in which a single red-orange larva was found in association with 2 *cooki* larvae. The usually orange but occasionally yellowish larvae are very placid, showing few signs of life, but, if removed from the coconut and placed on the hand or table they double up and catapult themselves through the air, with an audible snap.

Cyclorrhaphous larvae included Drosophilidae and Syrphidae in fermenting putrid coconuts, and the larvae of undetermined aquatic calypterate and acalyperate forms.

Biting activity. *Aedes cooki*, as with other members of the *scutellaris* group, is a diurnal biter and is common in most habitats encountered on the islands in its range. It has been collected biting man from sea level to the summit of Mount Talau, (198 m) on Vava'u, in all areas visited in Niue and is

said to be encountered even on the highest points on Niuafo'ou up to 227 m. The highest densities are encountered in the shade and tend to increase with increased densities of cover. Very high densities were not encountered as in some species in Tonga where the crab hole niche is present and utilized. It is not known whether *cooki* utilizes crab holes but the major islands in its range provide few areas suitable for extensive crab hole habitats. Biting-landing collections on Utungaki and Pangai Motu islands in the Vava'u group, among mangroves and near a lagoon where crab holes were observed, gave an average of 0.2 *cooki*/min based on 40 minutes of collecting. At least in these areas, crab hole habitation by *cooki* was not apparent. The highest densities were encountered at Tafolomahina in the center of Niue Island where biting-landing *cooki* were encountered at rates of 6 to 10 per minute. A systematic biting-landing survey was made in Ha'akiu village on Vava'u. Twenty-seven houses were surveyed by a 10 minute human bait collection in the shade near each house. The average biting rate was about 1 per minute (264 *cooki*/270 min). with a range of 0 to 76 (7.6/min). Seven (26%) of the stations yielded 10+ *cooki*, 5 had 1-9, 11 provided 1-4 and 4 were negative for *cooki*. There was a tendency for the highest densities to occur on the periphery. All of the negative sites were in the central portion of the village. It appears that *cooki* may have a greater tendency to bite and rest indoors than the other *scutellaris* species in the area. Indoor biting-resting collections made on Niue included: 6 in Alofi, our laboratory house (4), the treasure building (1), and the next door to the laboratory. A total of 13 females and 4 males were caught, all between 1000-1630 h. In a search for naturally infected *cooki*, 43 females (most freshly fed) were collected inside an isolated house, mainly in a partially screened kitchen, in Tafolomahina. This was the only occasion in all islands studied where large numbers of the *scutellaris* group were found resting in a house. Usually, it is a case of entering the house to feed and exiting immediately after feeding. The partial screening may have made the exit more difficult. In Vava'u, 27 houses were surveyed for indoor resting mosquitoes. Only 16 mosquitoes were captured of which 4 were males (3 *aegypti*, 1 *Cx. quinquefasciatus*) and 12 were females (7 *cooki*, 3 *Cx. quinquefasciatus*, 2 *aegypti*). The 7 *cooki* were in essence biting-landing females. All had stage II ovarian follicles, 5 with empty midguts, one fully fed with fresh blood and one with a partial meal of fresh blood suggesting that it had been disturbed while feeding. The *aegypti* included a female with stage V follicles and old blood, while the other had stage II follicles and empty midgut, i.e. a biting-landing rather than a resting female. The 3 *Cx. quinquefasciatus* were resting mosquitoes, freshly fed, with stage II or III ovarian follicles. Even though the numbers are small, it suggests that *cooki* on both Niue and Vava'u may prefer to bite indoors more than the other *scutellaris* group species in the Tonga area.

Fecundity - Individual egg batches were obtained from 63 *cooki* (Vava'u-21, Niue-29 and Niaufo'ou-13) ranging from 22 to 130 eggs per female, providing 3,831 eggs or a mean clutch size of 60.8 eggs. The median clutch was 55 and the mode 50 to 59 eggs per female. The median and ranges of Vava'u and Niue were similar, 51 and 52, and, 26-130 and 22-126, respectively; however, because of the 3 very large egg batches from Vava'u (114, 129, 130) providing 27.2% of the total eggs, the mean clutch was 65.3 as compared to 58.8 for Niue where the 2 large egg batches provided only 13.4% of the total. The egg batches in excess of 100 were 7.9% and they contributed 15.7% of the eggs.

Gonotrophic cycle. The length of the gonotrophic cycle for *cooki* on Vava'u during June 1975, was 72 to 73 hours from blood meal to oviposition. The figure was derived from 16 females with known feeding and oviposition times.

Oviposition began 70 to 75.5 hours after the blood meal with a mean of 72.3 h and a mode of 72 h. It appeared that the length of the gonotrophic cycle on Niue during April and May 1973 was longer by about 0.5 day, i.e. 3.5 days. However, only one female was timed to the hour and it oviposited at 72 hours. The other 12 were checked for oviposition only in the morning (0600-0800 h) and afternoon (1600-1800 h), consequently, the figures are crude but definitely in excess of 72 hours. The rough derived average was 83.3 hours from blood-feeding to oviposition. From data derived from dissection of 178 biting-landing *cooki* in Haakiu village, Vava'u, it was observed that 15.7% of the parous females had distended pedicels showing that they were returning for a blood meal within 24 hours of oviposition.

Autogeny. *Aedes cooki* was the 2nd species of the *scutellaris* group shown to be autogenous, i.e. capable of developing the first egg batch without a blood meal. This was observed in a colony derived from Niuafo'ou, in 1972. The first species observed to be autogenous was *kesseli* in 1970 (Hitchcock and Rozeboom 1973). Autogeny was also demonstrated in *cooki* from Niue and Vava'u in 1973 and 1975 (Hitchcock, unpublished data; Hoyer and Rozeboom 1976). Through our work, autogeny has been observed in all species and subspecies of the *scutellaris* group in the Tonga area but has not yet been described outside of the area in any member of the *scutellaris* group.

MEDICAL IMPORTANCE. *Aedes cooki* is the major vector of filariasis in its range. It was experimentally infected with *W. bancrofti* on Niue and found naturally infected with both *W. bancrofti* and *D. immitis* in Vava'u. This species was suspected to have been the major vector of the dengue-2 virus outbreak on Niue Island (1972) and is a suspect vector of both dengue-1 (1975) and dengue-2 (1974) viruses in Vava'u.

Filariasis. In *cooki*, experimentally infected on Niue, 50% of 30 females dissected from post-infection day 9 to 14 contained stage II or III larvae of *W. bancrofti*. The first active stage III larvae were observed on day 11, however, it was not until day 12 that infective stage larvae were observed migrating out of the thoracic area and into the head and mouthparts. Because of mass drug administration of Diethylcarbamazine citrate in progress on Niue at the time of the study, no naturally infected *cooki* were observed in the 115 parous *cooki* dissected. However, *cooki* was found naturally infected with *W. bancrofti* and *D. immitis* in females dissected from a biting-landing survey made in Ha'akiu village, Vava'u. One hundred seventy-eight *cooki* were dissected, of which 108 were parous (60.7%). Twenty-five filarial infections were recorded among 21 *cooki* - there were 8 infections with *W. bancrofti* and 17 infections with *D. immitis*, including: a multiple infection with *W. bancrofti*, a multiple infection with *D. immitis* and 2 mixed infections, i.e. *W. bancrofti* and *D. immitis*. Infective larvae (stage III) were recovered from 2 *cooki*: 9 stage III of *W. bancrofti* (6 head and mouthparts, 2 thorax, 1 abdomen); and 13 stage III of *D. immitis* (12 abdomen, 1 thorax). Interestingly, these were the 2 females with mixed infections, the first a 4-parous *cooki* also contained 4 stage I of *D. immitis* while the 2nd, a 3-parous female also had 9 stage I of *W. bancrofti*. The infection and infective rates based on the 108 parous *cooki* were: *W. bancrofti* - 7.4% and 0.93; and *D. immitis* 15.7% and 0.93% respectively. One hundred eighty-nine filaria larvae were recovered from the 108 parous *cooki* dissected (1.75/female) of which 38 were *W. bancrofti* (0.35/female) and 151 were *D. immitis* (1.4/female). The average worm burden per infected mosquito was: *W. bancrofti*, 4.8; and *D. immitis* 8.9. The average number of stage III larvae per parous and infected mosquito was *W. bancrofti*, 0.08 and 1.13; and for *D. immitis*, 0.12 and 0.77.

Dengue. An explosive outbreak of dengue-2 virus occurred on Niue during 1972. It appears that the usual vector, *aegypti*, is a recent immigrant to Niue and is now in the process of establishing itself there. It was becoming widely distributed by the time of our observations early in 1973, but it was always in association with, and less abundant than *cooki*, even in its most preferred larval habitats. Observations made during the outbreak on Niue by Dr. L. Rosen and Punapa Eric (personal communication), showed such low densities of *aegypti* that it could not have played a major role in the transmission of dengue-2 during the outbreak. Subsequent laboratory studies, with both *cooki* and *aegypti* from Niue Island, showed that *cooki* consistently supported salivary gland infections, (i.e. became infective) with the Niue strain of dengue-2, while it appeared that *aegypti* was refractory to salivary gland infection (Drs. D. Gubler and L. Rosen, personal communication). It appears that on both epidemiological and experimental grounds *cooki* was at least the major vector, if not the only vector on Niue at the time of the outbreak. During our study on Niue, the prevalence of *cooki* and *aegypti* in all larval habitats was 88.0% and 19.3% while for artificial containers, only, it was 81.1% and 43.2% respectively. *Aedes aegypti* was less frequent than *cooki* in all but 3 artificial containers: a canoe in Alofi and two 50 gallon drums, one in Avatele and one in Liku. The relative abundance of *aegypti* in Vava'u just after an outbreak of dengue-1 was also very low. The prevalence at the sites for *cooki* and *aegypti* were: all collections (77) 54.5% and 7.8%; artificial containers (27) 33.3% and 18.5%. The prevalence rates for the combined village surveys of Nioafu and Ha'akiu, for *cooki* and *aegypti*, were: all collections (39) 59.0% and 15.4%, artificial containers (18), 66.7% and 27.8% respectively, while the Breteau indices, based on 57 houses surveyed were: 40.4 and 10.5; and for artificial containers, 21.1 and 8.8 respectively. The number of immatures collected in the 77 samples were: *cooki* 1,802 and *aegypti*, only 26. For artificial containers it was: 151 and 18 respectively, i.e. nearly a 10-fold difference. Due to the low incidence of *aegypti* in peridomestic sites, it was not at a sufficient level to support the recent dengue outbreaks on Vava'u. Thus it appears that *cooki* was probably involved in transmission.

AEDES (STEGOMYIA) KESSELI HUANG AND HITCHCOCK, NEW SPECIES

(Figs. 4, 5, 6, 13, 14, 15, 16)

Aedes (Stegomyia) sp. Tafahi form, Huang 1977a: 291 (L*).

This species is named for Dr. John F. Kessel, in recognition and appreciation of his great contribution to the knowledge of subperiodic Bancroftian filariasis and its control in the South Pacific. As in *cooki*, except for:

MALE. *Head*. Proboscis dark scaled, sometimes with a few pale scales on the ventral side, longer than forefemur. *Thorax*. Median stripe from anterior margin of scutum narrows slightly posteriorly and forks at beginning of the prescutellar space; prescutellar line with a few narrow golden yellowish scales or sometimes absent; patches of broad white scales on propleuron, on the upper and lower portions of sternopleuron and on the upper and lower portions of mesepimeron, or sometimes the lower mesepimeron without scales; upper sternopleural scale patch reaches to anterior corner of sternopleuron; lower mesepimeral scale patch small and well separated from upper mesepimeral scale patch. *Legs* (Fig. 16). Hindfemur anteriorly with a broad white longitudinal stripe which widens at base and is narrowly

separated from the apical white scale patch; fore- and midtarsi with basal white bands on tarsomeres 1, 2; sometimes fore- and midtarsi with a basal white band on tarsomere 1 only; hindtarsus with a basal white band on tarsomeres 1-4, the ratio of length of white band to the total length of tarsomere is 0.25-0.33, 0.33, 0.40 and 0.50-0.60; tarsomere 5 all white or sometimes with a few dark scales on the ventral side; sometimes hindtarsus with basal white band on tarsomere 4 interrupted by a few dark scales on the ventral side or by a stripe of dark scales on the ventral side (Niuatoputapu specimens sometimes have hindtarsus with basal white bands on tarsomeres 4, 5 interrupted by a stripe of dark scales on ventral side); hindleg with tarsal claws equal, simple. *Abdomen* (Fig. 14). Segment I with white scales on laterotergite; tergum II dorsally dark, with basal lateral white spots only or sometimes with a small basal median spot as well; terga III-VI each with a subbasal median pale yellowish or white spot and with lateral white spots which are turned dorsomesally; sometimes terga IV, V with some pale scales on each side of the subbasal median spot forming a subbasal transverse pale dotted band; occasionally tergum VI also with a subbasal transverse pale dotted band; rarely terga III-V each with a complete subbasal transverse pale band (Niuatoputapu specimens sometimes have terga III-VI with complete subbasal transverse pale bands); tergum VII with lateral white spots only or sometimes with a small median spot as well.

Terminalia (Figs. 4, 13). Basimere 3.5 as long as wide, distimere simple, elongate, length of basimere, with a spiniform process and a few setae near apex; apical margin of tergum IX with middle truncated and with a hairy lobe on each side.

FEMALE. Essentially as in the male of *cooki*, differing in the following respects: *Head*. Palpus with white scales on less than apical half. *Abdomen* (Fig. 15). Terga II-VII with basal lateral white spots only or sometimes terga III-V with not very distinct subbasal pale yellowish spots as well; occasionally tergum VI also with a small subbasal pale spot as well; rarely terga III-IV each with a more or less complete subbasal transverse pale band and a dotted subbasal pale band on tergum V (Niuatoputapu specimens sometimes have terga III-V each with a more or less complete subbasal transverse pale yellowish band and a dotted subbasal pale band or subbasal pale spot on tergum VI). *Terminalia* (Fig. 6). Insula with minute setae and with 7 (6-8) larger setae on apical 0.4; apical margin of tergum IX with well-developed lateral lobes, each with 5 (3-5) setae.

PUPA (Fig. 4). *Cephalothorax*. Trumpet short, about 3.0 as long as wide at the middle; setae 1,3-C single, longer than 2-C, 2-C usually single (1, 2), 4,7-C usually double (1, 2), 8-C usually double (1-4), 10-C usually 3-branched (2-5), mesad and caudad of 11-C, 12-C usually double (1-3). *Abdomen*. Seta 1-II with 4-12 branches; 1-III usually double (1-6); 1-IV single or double; 5-IV-VI single, or sometimes 5-IV, V double; 5-IV, V usually long, reaching beyond posterior margin of following segment; 9-VI, VII usually single and simple, or sometimes barbed, much stouter and longer than preceding setae; 9-VIII with 2-8 branches, each barbed.

LARVA (Fig. 5). *Head*. Seta 6-C single or split at tip, 7-C with 2-4 branches; 11-C usually with 2,3 branches, 12,14,15-C usually double; mentum with 12,13 teeth on each side. *Thorax*. Seta 1-P usually 3-branched (2, 3), 5-P usually double, 7-P usually 3-branched (2, 3), 14-P usually 3-branched; 6-M with 4-6 branches; 8-M usually with 6,7 branches, 9-M 3-branched; 7-T usually with 6-8 branches, 9-T usually 3-branched (2, 3). *Abdomen*. Seta 6-I usually 4-branched (4, 5), 7-I usually double (1, 2); 6-II usually 4-branched

(3,4), 6-III-V double; 6-VI usually single (1,2); 1-VII usually 3-branched, 2-VII usually single (1,2); 3-VIII usually with 4,5 branches, comb of 8-14 scales, in a single row, each scale with rather distinct denticles at the base of the apical spine, sometimes comb scale with apical spine split at tip; anal segment with saddle incomplete, marginal spicules present; seta 1-X 2-branched, 3-X single or double; ventral brush with 4 pairs of setae on grid, each seta usually with 3,4 branches, sometimes 1 or 2 setae 2-branched; anal papillae 2.0-3.0 length of saddle. *Siphon*. Short, about 2.0 as long as wide, pecten teeth 8-16, evenly spaced, each tooth usually with 2 large and 1,2 small basal denticles; seta 1-S with 3-5 branches, inserted beyond last tooth and beyond the middle of the siphon.

TYPE-DATA. Holotype male (S. P.-I-4) with associated larval and pupal skins and terminalia slide (YMH-'72-3), Tafahi Island, Tonga, VIII-1971, SEAMP. Deposited in the USNM. Allotype female (S. P.-I-149) with associated larval and pupal skins, all with same data as holotype. Deposited in the USNM. Paratypes: 19 males, 9 females as follows: 9 males (S. P.-I-1,3,5,6,8,11, 12,13,16) with associated larval and pupal skins and terminalia slides (YMH-'72-1,2,4,5,6,7,8,9,10); 2 males (S. P.-I-36,125) with associated larval and pupal skins; 8 males (S. P.-I-55,56,97,98,100,104,128,162) with associated pupal skins; 9 females (S. P.-I-2,7,9,10,14,15,18,26,110) with associated larval and pupal skins, all with same data as holotype. Deposited in the USNM and BMNH. (All type materials were reared at SEAMP from eggs which were from Dr. J. C. Hitchcock's collection #7, females biting man on Tafahi Island, Tonga, 30-VI-1970).

DISTRIBUTION. This species occurs only in Tonga. In Tonga it is known from the following islands: Tafahi, Niuatoputapu, Hunganga, Motualanga, Nukunono, Tavili and Hakauto'utu'u (Map II). 1,874 specimens examined: 547♂, 650♀, 170♂ terminalia, 12♀ terminalia, 21 L, 288 individual rearings (186 l, 288 p).

TONGA. *Tafahi Island*, (VI-1969, individual rearings), 30♂, 24♀, 8♂ terminalia; (VI-VII-1970, individual rearings), 57♂, 37♀, 17♂ terminalia; (1970 progeny rearings), 25♂, 18♀, 11♂ terminalia; (1970, biting in field), 23♀; (VIII-1971, progeny rearings in SEAMP), 91♂, 71♀, 24♂ terminalia, 8♀ terminalia, 14 L, 170 individual rearings (80 l, 170 p); *Niuatoputapu Island*; (IV-1968, University of California, Los Angeles colony), 65♂, 135♀; (V-VII-1969, individual rearings), 44♂, 48♀, 8♂ terminalia; (VII-VIII-1970, individual rearings), 54♂, 45♀, 18♂ terminalia; (VII-VIII-IX-1970, progeny rearings), 56♂, 79♀, 19♂ terminalia; Falehau (VIII-1970, individual rearings), 39♂, 23♀, 18♂ terminalia; Vaipoa (IX-1970, individual rearings), 6♂, 10♀, 2♂ terminalia; *Hunganga Island*, (VIII-1970, individual rearings), 15♂, 26♀, 5♂ terminalia; *Motualanga Island*, (VIII-1970, individual rearings), 13♂, 16♀, 5♂ terminalia; *Nukunono Island*, (VIII-1970, individual rearings), 19♂, 18♀, 8♂ terminalia; *Tavili Island*, (VIII-1970, individual rearings), 1♀; *Hakautu'utu'u Island*, (IX-1970, individual rearings), 5♂, 6♀, 2♂ terminalia; (XI-1972, progeny rearings in SEAMP), 28♂, 70♀, 25♂ terminalia, 4♀ terminalia, 7 L, 118 individual rearings (106 l, 118 p).

TAXONOMIC DISCUSSION. *Aedes kesseli* is a member of the *scutellaris* subgroup, having the supraalar white line complete and well developed, with broad flat scales over the wing root and toward the scutellum. The adults are very similar to those of *upolensis* from Samoa, especially, when there is complete absence of the lower mesepimeral scale patch, or the presence of at most 3 scales in this region. It is also very similar to adults of *horrescens* and *polynesiensis* from Fiji, especially if the female has only basal lateral

white spots on the abdomen. It can be recognized, however, in having the dorsal surface of the hindfemur with the basal portion at least 0.25 white; in *upolensis*, *horrescens* and *polynesiensis* the dorsal surface of hindfemur has at most 0.12 of its surface white.

Aedes kesseli is most closely related to *cooki*. We are describing *kesseli* as a distinct species in spite of the fact that the claspette of the male terminalia of *kesseli* is indistinguishable from that of *cooki*. The larva of *kesseli* is strikingly different from that of *cooki* by the incomplete saddle. In this respect, *kesseli* is very similar to *upolensis*. However, it can easily be distinguished from *upolensis* by the absence of seta 13-P. The pupa is indistinguishable from that of *upolensis*.

The Niuatoputapu specimens differ rather markedly from the Tafahi specimens in that the abdominal terga III-VI sometimes have complete sub-basal transverse pale bands (in male) and abdominal terga III-V sometimes have incomplete or dotted sub-basal pale yellowish bands (in female). In other respects these populations appear to be identical.

There is considerable variation in *kesseli* from the different islands and even on the same island - individual, and geographic, but all the males we have examined conform to a single type which can be distinguished from those of *tongae tabu* and *tongae tongae* by the characters given in the key.

At the present time *kesseli* is the only known species of the *scutellaris* group on Niuatoputapu Group (Tafihi, Niuatoputapu) in the Tonga islands.

BIONOMICS. *Aedes kesseli* probably has the widest range of larval habitats of all species of mosquitoes in the Tonga area and is certainly on a par with the closely related, ubiquitous and wide ranging *Ae. polynensiensis*. It readily feeds on man and was found to be in the highest densities recorded for members of the group in the area. It has been found naturally infected with *W. bancrofti* and *D. immitis* on both Niuatoputapu and Tafahi, and is the most important vector of *W. bancrofti* in its range. Furthermore, it is from an area of very high endemicity of *W. bancrofti*. *Aedes kesseli* is the suspect vector of dengue-1 virus on Tafahi (1975) and may have been the major vector of dengue-1 on Niuatoputapu (1975). Field studies were made on Niuatoputapu and Tafahi: March and April 1968, May to July 1969, end of June to September 1970, and for Niuatoputapu only, September and October 1972.

Immature habitats. One hundred and sixty-three potential mosquito immature habitats were surveyed for *kesseli*, on the northern outliers of Niuatoputapu (125) and Tafahi (38) islands. Collections for Niuatoputapu include those made on the small island of Hunganga (16) and the islets of Motualango (4) Nukunono (2) Tavili (1) and Hakautu'utu'u (1), (see Map I and II). One hundred and fifty-two (93.3%) were positive for mosquitoes and 68.7% were positive for *kesseli* (Table 5). Only 11 sites (6.7%) were negative for mosquitoes. Of particular interest was the collection of *kesseli* from ground water on Niuatoputapu, an unusual niche for the *Ae. scutellaris* group, hence a brief description of each of the sites. The first was a borrow pit, 1.2 x 1.2 x 0.9 m, with 12.7 cm of water with many coconuts lying in the water. There was also a copious development of filamentous green algae. The water was semi-permanent, clear, fresh with a mud bottom and in partial shade alongside a road. The larvae were all 2nd stage and were numerous. Only *kesseli* was recovered from the site and because of the coconuts, one could speculate that the oviposition occurred in the coconuts and thence into the ground water. The 2nd site however, was 3.7 x 1.2 m with 7.6 to 30.6 cm of semi-permanent, clear, fresh water with a mud bottom and neither coconuts nor algae. It was in deep and partial shade alongside the road. It also contained larvae of *kesseli* in the

same stage as the previous site. The 3rd had characteristics more like a roadside puddle than a borrow pit - it was 3.7 x 4.6 m and 15.3-20.4 cm deep with turbid fresh water in full sun. It contained 3rd stage larvae of *Ae. vexans* (Meigen), *Cx. annulirostris* Skuse and *Ae. kesseli*. The well was on the southern side of the island in the shade of a large mango tree (*Mangifera indica* Linnaeus) at an agriculture farm. It was 0.9 m in diameter and 3.7 m down to the clear fresh water. It contained mainly *kesseli* with a few *Cx. quinquefasciatus* and *Cx. annulirostris*. Crab holes provided an excellent niche for *kesseli*. Only 7 collections were made from this category even though the site probably produces the greatest biomass of mosquitoes on Niuatoputapu, and the small associated islets. Some people call Niuatoputapu "mosquito island", and it is probable that the crab hole habitat of *kesseli* on Niuatoputapu is responsible for this name. Three of the crab holes were dug out at the time of collecting and had only *kesseli*, the turbid milky white water was black with pupae and larvae of *kesseli*. The other 4 were previously opened to catch the crab for eating. Three were 25.5-30.6 cm in diameter and about 20.4 cm to the water level with the submerged crab hole being 7.6-10.1 cm in diameter. The 4th was less altered and not in direct sunlight as were the other 3. These crab holes were ecologically altered from the freshly dug out sites and consequently, *vexans* was recovered from the 4 sites and in association with *kesseli* in 3. The water was brackish and turbid milky-white with water temperatures in the 3 larger holes 29°C, and in the smaller, 26.5° C. It was interesting that although the opened crab holes were directly exposed to full sunlight, and were acceptable to the ground pool inhabiting *vexans*, they still continued to be suitable for *kesseli*. The adult densities of *kesseli* encountered in dense crab hole areas could account for this phenomenon, as well as the utilization of the borrow pits, especially the one with more of the characteristics of a roadside puddle. Volcanic rock holes were found and collected from on Tafahi. They represented 3 distinct types. Those along the coast in open sunlight, often splashed by waves, contained *Cx. sitiens* (3/3), in one instance in association with *Cx. annulirostris*. Those in partial to deep shade collecting rain water, leaves and much detritus were found copiously producing *kesseli* (5/5). The 3rd type were 2 rather large shallow rock holes of clear fresh water and some emerged vegetation at an elevation of approximately 181 m. One was 1.5 x 0.8 m and 7.6 to 10.1 cm deep, with mainly *oceanicus* (usually a leaf axil breeder), a few *Cx. annulirostris* and a few *vexans*. The 2nd, in close proximity to the first, had an irregular shape about 1.1 m at its longest measurement and likewise 7.6 to 10.1 cm deep, was producing only *Cx. annulirostris*. Of 32 leaf axil collections, 6 were negative for mosquitoes, the remainder were positive for *oceanicus*, including 2 in association with *kesseli* in *Pandanus* on Niuatoputapu. However, like *cooki* on Vava'u, the only observed leaf axil harboring *kesseli* larvae was in *Pandanus*. Artificial containers, at least between March 1968 and October 1972, were of little significance on Niuatoputapu or Tafahi in either numbers of containers or mosquito production. The 9 collections from ground pools (including roadside puddles), swamps and marshes contained *vexans*, *Cx. sitiens* and *Cx. annulirostris*, but not *kesseli* and have been combined for convenience. The importance of sampling all of the available niches in an island situation can be easily seen with our collection of *kesseli*, a basically container-inhabiting species, from ground water in crab holes, borrow pits and a well.

Relative abundance of kesseli *in aquatic habitats*. Based on the arbitrary levels for abundance* by the number of immatures in the sample it was seen

*Abundant = 20+, common = 10-19, few = 1-9 immatures per sample.

that 58.0% of the samples positive for *kesseli* were considered abundant, 16.1% common and 25.9% few (Table 5). The natural immature habitats were: 60.2%, 12.6% and 27.2% respectively. The 5 volcanic rock holes on Tafahi positive for *kesseli* were all in the abundant range. Fifty-four percent of the tree holes were considered abundant, with the small tree holes 42.9% abundant, 21.4% common and 35.7% few, while the large tree holes were 78.9%, 5.3% and 15.8% respectively. All large tree holes on Tafahi were abundant. Sixty-five percent of the coconuts were graded abundant for *kesseli* while 30.0% were few. The fallen tree, fallen frond and 3 fallen coconut spathes all provided abundant immatures. The 2 leaf axil collections of *kesseli* from *Pandanus* on Niuatoputapu each provided few immatures of *kesseli* and abundant *oceanicus* in a ratio from 1:5 to 1:6 (17.8% *kesseli*). This compares with *cooki* from *Pandanus* in Vava'u at about 1:6 (15.7% or 1:6.4). One-third of the artificial containers positive for *kesseli* were classified abundant, 55.6% common and 11.1% few.

Immature habitat preference. *Aedes kesseli* may be the most ubiquitous in its choice of immature habitats of any of the *scutellaris* group, utilizing as noted above, 11 habitat categories. However, tree holes and coconuts are the dominant niches, with volcanic rock holes on Tafahi and crab holes on Niuatoputapu providing the 3rd major natural site. The invasion of ground water sites on Niuatoputapu is of ecological significance and could be related to both mosquito density and their invasion of the crab hole niche. The leaf axil appears to be of minor importance, with *Pandanus* providing the only positive collections. It is interesting to note that of the 15 collections made in *Pandanus* leaf axils, the 2 collections positive for *kesseli* were from "Paongo" (*Pandanus whitmeeanus* Martelli), even though collections were made in 4 other recognizable forms, i. e. "Tofua", "Kia", "Falahola" (*P. tectorius* var. *sinensis* Warburg) and "Fafa". The leaf axil collection of *cooki* in Vava'u was also from "Paongo." Unused water seal toilets provide ideal sites for *kesseli* either right-side-up or up-side-down. Because of their proximity to houses and their relative abundance on Niuatoputapu they probably provide the most important type of artificial container on the island.

Mosquito species composition at larval habitats. *Aedes kesseli* was found in association with 5 other species on Niuatoputapu: *Ae. aegypti*, *Ae. oceanicus*, *Ae. vexans*, *Cx. quinquefasciatus* and *Cx. annulirostris*. *Culex sitiens* was the only mosquito species on Niuatoputapu which was not found in association with *kesseli*. Although all species but *aegypti* were recovered from Tafahi, *kesseli* was never found in association with another species. Of the 152 immature collections positive for Culicidae, 112 contained *kesseli*, 4 *aegypti*, 27 *oceanicus*, 13 *vexans*, 5 *Cx. quinquefasciatus* and 8 *Cx. sitiens*. A summary of the species composition for all aquatic habitats is given in Table 6. It can be seen that 73.7% (112) of all positive sites contained *kesseli*. *Aedes kesseli* only was present in 65.1%. In addition, 17.1% produced only *oceanicus* or both *kesseli* and *oceanicus*. The residual 17.8% contained the other 5 species including the collection of *oceanicus* in association with both *vexans* and *Cx. annulirostris* from the clear shallow rock pool from Tafahi described above. *Aedes kesseli* was associated with *aegypti* on 3 occasions: a cistern, a small tree hole and a large tree hole also in association with *Cx. quinquefasciatus*; *vexans* 4 times: opened crab holes, and a borrow pit (characteristic of a roadside puddle) along with *Cx. annulirostris*; *Cx. quinquefasciatus* 5 times: a well and a canoe both also in association with *Cx. annulirostris*, a log drum, a small tree hole and a large tree hole, also with *aegypti* and *Cx. annulirostris* on the 3 occasions cited above. *Aedes aegypti* was collected from a tin can in the laboratory.

TABLE 5. Immature habitats sampled and the relative abundance of *Aedes kesseli* by category.

Immature habitat category	Niuatoputapu						Tafahi						Total					
	Number collected	Negative for mosquitoes	Positive for *Ae. kesseli*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. kesseli*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. kesseli*	A	C	F
Ground pool, swamp and marsh	9	0	0	-	-	-	0	-	-	-	-	-	9	0	0	-	-	-
Well	1	0	1	1	0	0	0	-		-	-	-	1	0	1	1	0	0
Borrow pit	3	0	3	1	0	2	0	-	-	-	-	-	3	0	3	1	0	2
Crab hole	7	0	6	4	2	0	0	-	-	-	-	-	7	0	6	4	2	0
Volcanic rock hole	0	-	-	-	-	-	10	0	5	5	0	0	10	0	5	5	0	0
Tree hole	52	1	51	26	7	18	10	0	10	7	3	0	62	1	61	33	10	18
(Small)	(38)	(1)	(37)	(16)	(6)	(15)	(5)	(0)	(5)	(2)	(3)	(0)	(43)	(1)	(42)	(18)	(9)	(15)
(Large)	(14)	(0)	(14)	(10)	(1)	(3)	(5)	(0)	(5)	(5)	(0)	(0)	(19)	(0)	(19)	(15)	(1)	(3)
Fallen tree	1	0	1	1	0	0	0	-	-	-	-	-	1	0	1	1	0	0
Fallen frond	1	0	1	1	0	0	0		-	-	-	-	1	0	1	1	0	0
Coconut	19	3	16	11	1	4	4	0	4	2	0	2	23	3	20	13	1	6
Leaf axil	23	4	2	0	0	2	9	2	0	-	-	-	32	6	2	0	0	2
(Giant talo)	(5)	(0)	(0)	(-)	(-)	(-)	(2)	(0)	(0)	(-)	(-)	(-)	(7)	(0)	(0)	(-)	(-)	(-)
(Talo)	(4)	(0)	(0)	(-)	(-)	(-)	(5)	(1)	(0)	(-)	(-)	(-)	(9)	(1)	(0)	(-)	(-)	(-)
(*Pandanus*)	(13)	(3)	(2)	(0)	(0)	(2)	(2)	(1)	(0)	(-)	(-)	(-)	(15)	(4)	(2)	(0)	(0)	(2)
(Pineapple)	(1)	(1)	(0)	(-)	(-)	(-)	(0)	(-)	(-)	(-)	(-)	(-)	(1)	(1)	(0)	(-)	(-)	(-)
Spathe (coconut)	2	0	2	2	0	0	1	0	1	1	0	0	3	0	3	3	0	0
Subtotal Natural sites	118	8	83	47	10	26	34	2	20	15	3	2	152	10	103	62	13	28
Artificial container	7	1	5	3	2	0	4	0	4	0	3	1	11	1	9	3	5	1
(Small)	(4)	(1)	(2)	(1)	(1)	(0)	(0)	(-)	(-)	(-)	(-)	(-)	(4)	(1)	(2)	(1)	(1)	(0)
(Large)	3)	(0)	(3)	(2)	(1)	(0)	(4)	(0)	(4)	(0)	(3)	(1)	(7)	(0)	(7)	(2)	(4)	(1)
Total	125	9	88	50	12	26	38	2	24	15	6	3	163	11	112	65	18	29

A = abundant 20+; C = common 10-19; F = few 1-9 immatures per sample.

TABLE 6. Mosquito species composition at larval habitats.

Species	Total	Niuatoputapu	Tafahi
(No mosquitoes found)	(11)	(9)	(2)
Ae. kesseli only	99	75	24
Ae. kesseli with *Ae. aegypti*	2	2	0
Ae. kesseli, Ae. aegypti and *Cx. quinquefasciatus*	1	1	0
Ae. kesseli with *Ae. oceanicus*	2	2	0
Ae. kesseli with *Ae. vexans*	3	3	0
Ae. kesseli, Ae. vexans and *Cx. annulirostris*	1	1	0
Ae. kesseli with *Cx. quinquefasciatus*	2	2	0
Ae. kesseli, Cx. quinquefasciatus and *Cx. annulirostris*	2	2	0
Ae. aegypti only	1	1	0
Ae. oceanicus only	24	17	7
Ae. oceanicus, Ae. vexans and *Cx. annulirostris*	1	0	1
Ae. vexans only	1	1	0
Ae. vexans and *Cx. sitiens*	1	1	0
Ae. vexans, Cx. sitiens and *Cx. annulirostris*	2	2	0
Ae. vexans with *Cx. annulirostris*	4	4	0
Cx. sitiens only	3	1	2
Cx. sitiens with *Cx. annulirostris*	2	1	1
Cx. annulirostris only	1	0	1
Total	163	125	38

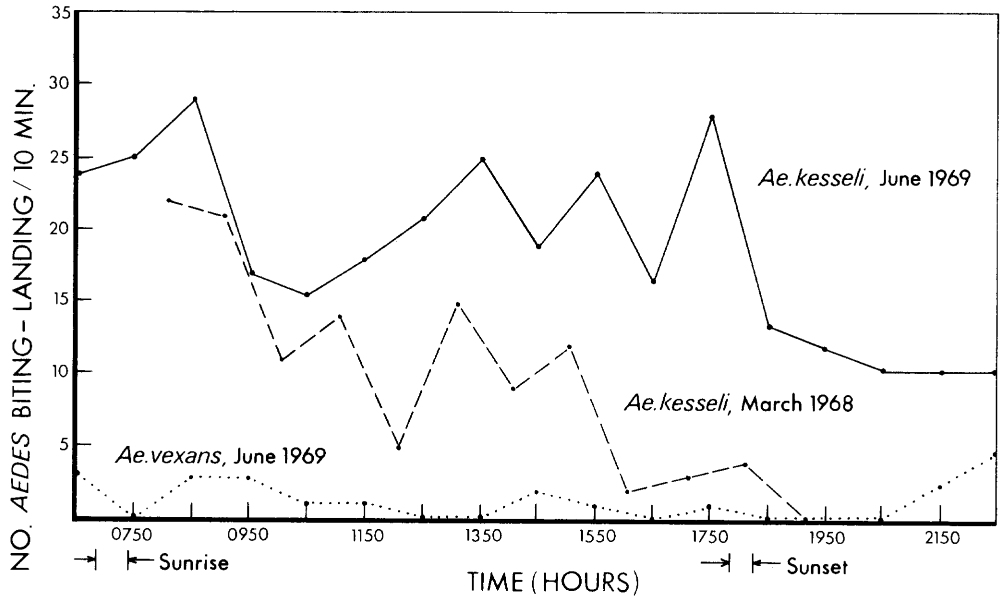
Aedes vexans was the only species found in an open crab hole and in the ground pools (of various types) with *Cx. annulirostris* 6 times, *Cx. sitiens* once and with both twice. *Culex sitiens* was also recovered from volcanic rockholes, once with *annulirostris* and again with *annulirostris* from a marshy depression. *Culex annulirostris* was also collected in a coastal rock hole on Tafahi.

Invertebrate fauna associated with mosquito larval habitats. Unfortunately, the data are fragmentary for 1969 and 1970 since the associated invertebrates were recorded separately and are not available for comprehensive interpretation. The phyla Platyhelminthes, Aschelminthes, Mollusca and Arthropoda were recovered from samples. The minute milky white platyhelminth, probably *Dendrocoelum*, was recovered from the leaf axil of pineapple. Aschelminthes, all Rotifera, were recovered from 4 of the 18 tree holes in 1972. Mollusca were represented by small gastropods also from 4 of the 18 tree holes but not associated with the Rotifera. They have also been found in coconut shells. Non-dipterous arthropods included: surface mites (Acarina) in tree holes and coconut shells; Crustacea included *Daphnia* in tree holes, and along with ostracods in ground water; a crab was found in a tree hole on Hunganga Island. Collembola were collected in tree holes, coconut shells and a tin can, while Coleoptera larvae were in the tin can and coconuts, and Odonata naiads were

observed in ground pools.

Non-culicid Diptera associated with kesseli. Ceratopogonidae were by far the most common invertebrate associated with *kesseli.* They were in nearly all tree hole collections including 16/18 (88.9%) in 1972 (in 6 of 7 species of trees sampled). They were in all volcanic rock holes that were positive for *kesseli* and also found in coconut shells and artificial containers. All specimens collected were *Dasyhelea hitchcocki* which was described by Wirth (1976) from specimens collected by one author (J. H.) on Niuatoputapu and its islets and Tafahi in 1969 and 1970. Chironomidae were collected infrequently from tree holes, usually large ones, and always in association with *kesseli* and *D. hitchcocki.* Psychodidae from a volcanic rock hole on Tafahi and occasional tree holes were *Telmatoscopus vitiensis* and were associated with *D. hitchcocki.* Cecidomiidae were common in coconut shells and in no other breeding site; all were *Resseliella* sp. Cyclorrhaphous larvae of the family Syrphidae were collected in a canoe.

Biting activity. Aedes kesseli, a primarily diurnal biter, is common in all areas and habitats within its range with the exception of the open beach areas. It has been collected from sea level to the summit of Tafahi Island (606 m) where it was captured at biting rates in excess of 10 per minute on 30 March 1968. The highest biting densities ever encountered in 8 years of working with the *scutellaris* group in the South Pacific were those of *kesseli.* During village surveys utilizing standardized 10 minute biting-landing samples, a record of 250 *kesseli* were obtained from house 24 (Falehau) on 13 April 1968 between 0937 and 0947 h. The house was located on the end of the village near an extensive crab hole habitat area. However, the greatest densities outside of the village situation were encountered on Hunganga Island a few hundred meters across a lagoon from Hihifo village on 25 September 1972, where we encountered a multitude of *kesseli* in partial shade near the shore of the lagoon around 1000 hours. In less than 30 m into the island, we continuously encountered hoards with 200-300 on each pant leg, with clouds swarming around at an estimate of over 1,000 per person. A few sweeps of a collecting net provided a "handful" and we actually ran to the shore and into the lagoon to escape. Although *kesseli* was abundant in tree holes and coconuts the biomass produced was insignificant to that produced by the crab hole niche. Surveys of the 4 villages were made in 1968 (Hitchcock 1969), 1969 and 1970 providing 6,440 *kesseli* from 417 10 minute biting-landing stations averaging 15.4 per 10 minutes (1.5/min). Of the stations, 14.4% (60) were negative for *kesseli* while 44.1% (184) provided 10 or more (one or more per minute). The 10 minute biting-landing rates for the 4 villages were: Hihifo 8.1, Vaipoa, 12.2, Falehau 46.2 and Kolokakala 12.0. In general, the highest densities of *kesseli* are at the periphery of the village (the highest densities encountered were on the eastern side of Falehau in closest proximity to the extensive crab hole habitats). The lowest densities were usually encountered along the sea front and in the more central areas within a village. Graph 1 shows the diurnal biting activity of *kesseli* from the average of 2 collections in June 1969 based on 10 minute periods centered around 50 minutes past the hour for 17 consecutive hours from 0644-0654 h prior to sunrise, utilizing a flashlight and continued until 2245-2255 h. Sunset was prior to the 1845-1855 h collection when artificial light was again needed. The graph shows a peak period of activity around 0900 (within 2 hours of sunrise), followed by a low around 1000 and 1100 h with increased activity throughout the afternoon followed by another peak just before sunset. Interestingly, after sunset (1800), although there was a drop from the late afternoon peak, biting activity remained relatively constant until collections



Graph 1

were terminated at 2255 h. The same location was sampled during March 1968 commencing at 0820-0830 h and terminating (14 hours later) at 1917-1927 h when no *kesseli* but 2 *vexans* were collected. This study is also plotted and depicts a "depletion" type curve with a single peak during the first collection period. During the 1969 study, 23 *vexans* were recovered during 10 collection periods (see graph). Five *Ae. oceanicus* were also collected from 1750 to 2250 h, with a single *Cx. quinquefasciatus* at 2150 h and a *Cx. annulirostris* at 2250 h. There appears to be a preference for *kesseli* to bite a standing person on the feet, ankles and lower leg, rather than the larger area presented by the body above the knee. The opportunity arose to measure this observation in an inland bush farm near mid-island on the west end of Niuatoputapu on 14 September 1970 between 1020 and 1040 h. Based on 2 pairs of simultaneous 10 minute collections, 75.9% of the 332 biting-landing females were captured below the knee, while only 24.1% were from the body above the knees. The biting rates for below the knees were 9.6 and 15.6 per minute while they were 1 per minute in the 2 simultaneous collections above the knees. *Aedes kesseli* shows a strong endophagic behavior that appears to be of a greater degree than that observed in *cooki*. When the family of one author (J. H.) was living in Niuatoputapu (June-September 1970) in a coconut thatched house, with an adjoining kitchen which was open between the low wall and the roof, high biting-landing rates were encountered. The bed net was used by the family in the daytime for resting, reading and playing cards, etc. to keep from being bitten by the highly endophagic *kesseli*. While preparing breakfast in the adjoining kitchen, the

attack rates were 2-10 per minute; often the children would remain within the mosquito net inside the house while breakfast was being prepared. The biting rates in the kitchen were seldom less than 1 or 2 per minute at any time during the day. The laboratory was a small bedroom in an old European style house with wooden walls, a corrugated iron roof plus a ceiling. The windows were partially screened as well as the entry door. Attempts were made to make it as mosquito-proof as possible, even so, *kesseli* were collected biting throughout the daylight hours.

Fecundity. Forty-one *kesseli* females provided individual egg batches which ranged from 21 to 112 eggs per clutch. The total of 1,971 eggs gave a mean clutch size of 48.1 per female. The median was 44 eggs and the mode was 30-39 eggs per female with a smaller but noticeable mode in the 60-69 range. When *kesseli* is compared with *cooki,* it shows a reduced fecundity with both the median and mean clutch size reduced by a factor of about 10 eggs per female.

Gonotrophic cycle. The length of the gonotrophic cycle for *kesseli* on Niuatoputapu from 23 September to 8 October 1972 was approximately 76 hours from blood meal to oviposition (range 72.0-77.5 h). The derivation of this figure was based on 12 females whose blood feeding and oviposition times was known (916.5 h/12 females). Thirty-nine of 51 females (76.5%) commenced oviposition on the 3rd calendar day from feeding; while 17.6% (9) commenced oviposition on the 4th day, however, 4 of these 9 females had taken their blood meals after 1400 hours. Three females (5.9%) commenced oviposition on the 2nd calendar day, however, the first eggs were not observed until evening of that day.

Autogeny. Aedes kesseli was the first member of the *scutellaris* group shown to be autogenous (Hitchcock and Rozeboom 1973). The first observation of autogeny was at 1100 hours, 2 August 1970, on Niuatoputapu. A 2nd generation adult, of a colony established from wild caught females on Tafahi, 30 June 1970, was dissected after it had fed on a donor the previous night (1700-1730 h). The female had 36 fully developed eggs (stage V) - within 18 hours of its first blood meal. The average time from blood meal to oviposition was shown to be around 76 hours at this time of the year on Niuatoputapu. Two unfed females were then dissected, they too showed autogenous development - one with stage IV eggs and the other with 19 stage V eggs, and one dilatation on most ovarioles.

Mermithid parasitism on kesseli. Parasitism of mosquitoes by mermithid nematodes (Enoplida: Mermithidae) has not been reported for the Kingdom of Tonga. While dissecting the human bait caught *kesseli* in 1970, 5 females were observed with mermithids: Niuatoputapu - Hihifo one in a 1-P female; Falehau one in a 1-P; and 3 on Tafahi - 2 in a 2-P, one in a 1-P and one in a nulliparous female. All mermithids were observed in the abdomen. The infection rate of mermithids in female *kesseli* was 0.57%(5/878) for 1970 which was 50% of that for the 1970 infective larvae rate for *W. bancrofti* of 1.1%. Three of 115 (2.6%) of the female *kesseli* dissected on Tafahi were infected. It is interesting that no mermithids were observed in the dissections of 1968 (738) and 1969 (880); if they were present in those samples they should have been encountered.

MEDICAL SIGNIFICANCE. *Aedes kesseli* is the major vector of filariasis on Niuatoputapu and Tafahi and has been found naturally infected with *W. bancrofti* and *D. immitis*. Since *aegypti* has not been found in larval surveys or biting on Tafahi, the probable vector of dengue-1 on Tafahi (1975) was *kesseli* and it was probably the major vector of dengue-1 on Niuatoputapu during the same explosive outbreak in 1975.

Filariasis. Aedes kesseli is an excellent vector of *W. bancrofti*. Systematic biting-landing mosquito surveys were made in the 3 villages on Niuatoputapu (Hihifo, Vaipoa andFalehau) and Kolokakala on Tafahi in 1968 (Hitchcock 1969), 1969 and 1970. A total of 2,496 *kesseli* were dissected from the 12 village surveys providing 139 *W. bancrofti* infections, giving an overall infection rate of 5.6%. Twenty females harbored stage III larvae for an infective rate of 0.8%. The mean number of *W. bancrofti* larvae per infected *kesseli* was 7.5 (1,047/139). The maximum and mean worm burdens observed in wild caught *kesseli* by developmental stage were: stage I larvae - 61 and 8.4 (645/77), stage II larvae - 43 and 7.5 (314/42) and stage III larvae - 14 and 4.4 (88/20). Only 5 multiple infections of *W. bancrofti* were observed in *kesseli* during the study: 3 stage I + II, 1 stage I + III, and 1 stage II + III. Also, 5 mixed infections were observed all in association with *D. immitis*: 2 - stage III *bancrofti* + stage I *immitis*, 1 - stage III *bancrofti* + stage II *immitis*, 1 - stage II *bancrofti* + stage III *immitis* and 1 - stage I *bancrofti* + stage III *immitis*. *Aedes kesseli* from human bait collections in the bush and along the road between Vaipoa and Falehau have also been found naturally infected and infective for *bancrofti*. *Aedes kesseli* appears to be a relatively good vector of D. *immitis*. Thirty-four naturally infected *kesseli* were recovered during the village surveys giving a 1.4% infection rate while the infective rate was 0.28% (7/2,496). The average worm burden among infected *kesseli* was quite high, 8.8 larvae (299/34). The maximum and mean worm burden per mosquito by stage was: stage I - 40 and 11.5 (196/17), stage II - 27 and 8.2 (82/10) and stage III - 2 and 1.3 (8/6). It should also be mentioned that *Ae. oceanicus* has been found infected with infective larvae of both *W. bancrofti* and *D. immitis* and appears to be an efficient vector of *bancrofti* on Tafahi and Niuatoputapu (Hitchcock 1970). The potential transmission index (Bonnet et al. 1956) for *kesseli* on Niuatoputapu and Tafahi based on the 3 years of surveys was 157.5 (mosquito density of 1.5/min x 0.42 larvae/mosquito x 250).

Dengue. An explosive outbreak of dengue-like illness occurred on Tafahi and Niuatoputapu in May 1975 (presumably dengue-1). Unfortunately, serological confirmation and isolation of the virus was not obtained due primarily to the remoteness of the islands. However, the outbreak was characteristic of the dengue-1 which was present in the Kingdom, but appeared to be more explosive and apparently more virulent than in the other areas. Intensive biting-landing surveys and larval surveys made on Tafahi during 1968, 1969 and 1970 did not indicate the presence of *aegypti*. Similar surveys on Niuatoputapu during 1968, 1969, 1970 and 1972 showed the presence of *aegypti* only in the village of Hihifo and only at a very low level. *Aedes kesseli* is present in high densities on both islands and is exceptionally numerous in the village of Falehau where the outbreak was reported to have started. Because of the high densities of *kesseli*, the very explosive nature of the outbreak, the lack of *aegypti* on Tafahi in the recent past, as well as the low levels of *aegypti* on Niuatoputapu less than 2 years prior to the outbreak, it appears that *kesseli* is the only suspect vector on Tafahi and it is also likely to have been the major vector of the dengue-like illness on Niuatoputapu.

AEDES (STEGOMYIA) TONGAE TONGAE EDWARDS
(Figs. 7, 8, 9, 13, 14, 15, 16)

Aedes (Stegomyia) variegatus var. *tongae* Edwards 1926: 103 (♂*, ♀).
Aedes (Stegomyia) tongae of Belkin 1962: 475 (in part).
Aedes (Stegomyia) tongae Edwards, Huang 1972: 340 (♂*, ♀).

MALE. As in *cooki*, except for: *Head*. Proboscis dark-scaled, with some pale scales on the ventral side, slightly longer than forefemur; palpus slightly shorter than proboscis. *Thorax*. Scutum with median stripe from anterior margin, narrows slightly posteriorly and forks at beginning of the prescutellar space; prescutellar line and posterior dorsocentral line distinct, well developed, with narrow yellowish pale scales; the apical dark spot of the midlobe rather small; lower mesepimeral scale patch of medium size and narrowly connected to or sometimes separated from, the upper mesepimeral scale patch. *Legs* (Fig. 16). Fore- and midtarsi with a basal white band on tarsomeres 1, 2; hindtarsus with a basal white band on tarsomeres 1-4, the ratio of length of white band to the total length of tarsomere is 0.33, 0.33, 0.40 and 0.40-0.60; sometimes hindtarsus with a basal white band on tarsomere 4 interrupted by a few dark scales on ventral side as well, or basal white bands on tarsomeres 4, 5 interrupted by a stripe of dark scales on ventral side; sometimes hindtarsus with a basal white band on tarsomere 4 interrupted by a few dark scales on ventral side as well, or basal white bands on ventral side. *Abdomen* (Fig. 14). Segment I with white scales on laterotergite and usually with a median pale spot as well; tergum II with a distinct median spot and with lateral white spots, or sometimes tergum II dorsally dark, with lateral white spots only; terga III-VI each with a complete sub-basal transverse pale band and with lateral white spots which are connected to the tergal band; tergum VII varied, with lateral white spots only or with a sub-basal median spot as well, or with sub-basal transverse complete or dotted band. *Terminalia* (Figs. 7, 13). Claspette with apical 0.28 usually slightly upturned and a basosternal angle present in lateral aspect (dissected claspette), usually with 6 (5-7) modified setae in a row on apical 0.20-0.25 of sternal side, lateral surface with fine setae extending basad to about level of modified setae, or to 0.33 of the entire claspette length; the modified setae rather stout and distinct.

FEMALE. Essentially as in the male of *cooki*, differing in the following respects: *Head*. Palpus with white scales on apical half. *Thorax*. Apical dark spot of midlobe sometimes large. *Abdomen* (Fig. 15). Terga III-VI usually with complete or dotted subbasal transverse pale bands and connected to the lateral white spots; sometimes tergum VI with a subbasal median pale spot and with lateral white spots which are turned dorsomesally; rarely tergum VI with lateral white spots only; rarely terga III-VI each with a median pale spot and lateral white spots which are turned dorsomesally; tergum VII varied, as in the male. *Terminalia* (Fig. 9). Insula with minute setae and with 6 larger ones on apical 0.4; apical margin of tergum IX with well-developed lateral lobes, each with 5 (4-6) setae.

PUPA (Fig. 7). *Cephalothorax*. Seta 1-C usually single, long, much longer than 2, 3-C, 3-C single, 4, 7, 12-C usually double (1, 2), 5-C usually double (1-3), 8-C usually with 2-4 branches, 9-C single, 10-C usually 3-branched (2-5), mesad and caudad of 11-C. *Abdomen*. Seta 1-II with 4-9 branches; 1-III usually double (1-4); 1-IV usually single (1, 2); 5-IV-VI usually single, or some-

times 5-IV, V double, short, not reaching beyond posterior margin of following segment; 9-VIII usually with 2 main stems (2-6) and lateral branches of varying length.

LARVA (Fig. 8). *Head.* Seta 6-C usually single (1,2), 7-C usually 3-branched (2,3), 10,13-C usually double (1,2), 11-C usually with 3-5 branches, 12-C double, mentum with 9-11 teeth on each side. *Thorax.* Setae 1,4,7,14-P usually double (2,3), 9-M usually double (2,3), 7-T usually with 4-6 branches. *Abdomen.* Seta 6-I usually 4-branched (3-5), 7-I usually double (1,2); 6-II usually 3-branched (3-5), 1-VII usually 3-branched (2-4), 2-VII usually single (1,2); 1,5-VIII usually with 3-5 branches, comb of 8-16 scales, in a single row, each scale with fine denticles at the base of the apical spine; seta 2-X usually 3-branched (2-4), 3-X usually single (1,2), ventral brush with 4 pairs of setae on grid, each seta usually double, 4a,b-X sometimes single, rarely 3-branched; anal papillae 2.5-3.5 length of saddle. *Siphon.* Short, about 2.0-2.6 as long as wide, pecten teeth 8-20, evenly spaced, each tooth usually with one large and 1,2 small basal denticles; seta 1-S with 2-4 branches.

TYPE-DATA. *Aedes (Stegomyia) variegatus* var. *tongae* Edwards, type-male with associated terminalia on a slide, in BMNH; type-locality: Ha'apai, Tonga, 26-II-1925 (P. A. Buxton and G. H. Hopkins).

DISTRIBUTION. This subspecies is presently known only from Tonga. In Tonga, it is known from the Ha'apai Group (Map V).

3,413 specimens examined: 629♂, 778♀, 179♂ terminalia, 6♀ terminalia, 409 L, 845 individual rearings (569 l, 843 p).

TONGA. *Ha'apai Group*: (II-1925, P. A. Buxton and G. H. Hopkins), 1♂, 2♀, 1♂ terminalia; *Lifuka Island,* (XI-XII-1971 progeny rearings in SEAMP), 178♂, 178♀, 69♂ terminalia, 1♀ terminalia, 71 L, 283 individual rearings (171 l, 283 p); (XI-1971 individual rearings), 13♂, 27♀, 2 ♂ terminalia, 15 L; *Luahoko Island,* (XI-1971 progeny rearings in SEAMP), 4♂, 5♀, 4♂ terminalia, 1 L, 12 individual rearings (12 l, 11 p); (XI-1971 individual rearings), 17♂, 23♀, 4♂ terminalia; *Ha'ano Island,* (VIII-1973 progeny rearings in SEAMP), 226♂, 255♀, 46♂ terminalia, 5♀ terminalia, 56 L, 497 individual rearings (358 l, 497 p); (1973 Coll. 181 & Coll. 182), 97♂, 126♀; (XI-1971 individual rearings), 10♂, 11♀, 2♂ terminalia, 14 L, 14 individual rearings (6 l, 14 p); *Foa Island,* (XI-1971 individual rearings), 2♂, 1♀, 9 individual rearings (8 l, 9 p); *Limu Island,* (XI-1971 individual rearings), 4♂, 10♀, 4♂ terminalia, 42 L; *Luangahu Island,* (XI-1971 individual rearings), 6♂, 13♀, 3♂ terminalia, 29 L; *Nukunamo Island,* (XI-1971 individual rearings), 6♂, 14♀, 4♂ terminalia, 56 L, 19 individual rearings (9 l, 18 p); *Tatafa Island,* (XI-1971 individual rearings), 2♂, 9♀, 2♂ terminalia; *Tofanga Island,* (XI-individual rearings), 5♂, 1♀, 3♂ terminalia, 23L, 7 individual rearings (3 l, 7 p); *Uanukuhahake Island,* (XI-1971 individual rearings), 2♂, 1♂ terminalia, 14 L, 4 individual rearings (2 l, 4 p); *Uanukuhihifo Island,* (XI-1971 individual rearings), 3♂, 3♀, 3♂ terminalia, 15 L; *Uiha Island,* (XI-1971 individual rearings), 28♂, 30♀, 6♂ terminalia; *Uoleva Island,* (XI-1971 individual rearings), 1♂, 2♀, 1♂ terminalia, 24 L; *Tofua Island,* (V-VI-1963, UCLA collection), 24♂, 40♀, 24♂ terminalia, 40 L; *Matuku Island,* (V-VI-1963, UCLA collection), 28♀, 9 L.

TAXONOMIC DISCUSSION. *Aedes tongae tongae* is a member of the *tongae* complex *(cooki, kesseli, tongae tongae* and *tongae tabu),* which is mainly confined to the Tonga islands, and appears to be a form native to the Ha'apai Group. It is a very plastic, adaptable, and highly variable subspecies, which apparently is in the process of evolving into more or less distinct forms within the Tonga islands. Considerable individual, ecological, and geographical variation is evident.

The females can easily be distinguished from those of *cooki* and *kesseli* by abdominal tergum VI which usually has a complete or dotted subbasal transverse pale band that is connected to the lateral white spots. In this respect, *tongae tongae* is extremely similar to *tongae tabu* but can be distinguished from *tongae tabu* by the characters in the key. However, these characters are subject to variation.

The male terminalia are of the type found in *upolensis, pseudoscutellaris, cooki, kesseli* and *tongae tabu*. *Aedes tongae tongae* is closer to *cooki, kesseli,* and *tongae tabu* in having the claspette with distinctly flattened, sharply pointed modified setae on the sternal side in lateral aspect (dissected claspette), and the lateral surface of the claspette with fine setae extending basad to at most 0.4 of the entire claspette length. However, it can easily be distinguished from those of *cooki* and *kesseli* by the claspette with 5-7 modified setae in a row on the apical 0.20-0.25 of the sternal side, the modified setae rather stout and distinct, and with a basosternal angle in lateral aspect (dissected claspette). In this respect, *tongae tongae* is extremely similar to *tongae tabu* but can be distinguished by the lateral surface of claspette which has setae extending basad to 0.20-0.33 of the entire claspette length. In *tongae tabu,* the lateral surface of the claspette has setae extending basad to 0.28-0.40 of the entire claspette length.

The pupa is indistinguishable from those of *polynesiensis* and *tongae tabu.*

The larva shares a number of characters with *pseudoscutellaris, polynesiensis, rotumae, cooki* and *tongae tabu.* It is closer to those of *cooki* and *tongae tabu* with setae 5-M double. It can, however, be distinguished from that of *cooki* by the setae 4a,b-X usually single or double. In this respect, *tongae tongae* is extremely similar to that of *tongae tabu* but can be distinguished from that of *tongae tabu* by the setae 4a,b-X usually double (1,2). In *tongae tabu* the setae 4a,b-X are usually single (1,2).

Aedes tongae tongae closely resembles *cooki* and *tongae tabu.* As a result, both *cooki* and *tongae tabu* were mistaken for *tongae tongae* in the past. The present studies indicate that *tongae tongae* can be differentiated from closely related members of the *scutellaris* group only by characters in the male terminalia. Since there is a clear-cut, nonoverlapping difference in the male terminalia between *tongae tongae* and *cooki* (although occasionally the differences between them tend to be very slight, but constant), we suggest that these 2 taxa are specifically distinct. On the other hand, since there are no clear-cut differences in the male terminalia between *tongae tongae* and *tongae tabu,* we propose that these 2 forms are at most only subspecifically distinct.

The character in the larva, seta 4a-X branched or single, used by Ramalingam and Belkin (1965) and Ramalingam (1976) to separate *tongae tongae* and *tongae tabu,* is not always reliable. It is unlike those of *polynesiensis* and *pseudoscutellaris* in which seta 4a-X branched or single is a reliable character.

At the present time *tongae tongae* is the only known member of the *scutellaris* group on the Ha'apai Group (Lifuka, Luahoko, Ha'ano, Foa, Limu, Luangahu, Nukunamo, Tatafa, Tofanga, Uanukuhahake, Uanukuhihifo, Uiha, Uoleva, Tofua, Matuku), in the Tonga islands.

BIONOMICS. *Aedes tongae tongae* is a diurnal biter common on all islands of the Ha'apai group (numbering over 60) and the only species encountered on many of the small uninhabited islands. It is the suspect vector of, and probably the major vector of, subperiodic *W. bancrofti* in Ha'apai. It may also be involved in the transmission of *D. immitis* and the dengue viruses. Field studies were made from 30 October to 2 December 1971 and on 9 August 1973,

from 13 islands of the group. Two additional islands were sampled by S. Ramalingham in 1963.

Immature habitats. Sixty-eight potential sites were surveyed for immature mosquitoes on 13 islands[1] of the Ha'apai group. Sixty-one of the 68 potential sites contained mosquitoes of which 49 were positive for *tongae tongae* (Table 7). Seven sites were negative for mosquitoes: 1/6 ground pools, 4/42 tree holes, 1/6 coconuts, and 1/5 leaf axils. None of the ground water samples contained *tongae tongae.* The few positive leaf axil samples made during the study had only *Ae. oceanicus.* However, in 1963, Ramalingham[2] made 2 leaf axil collections on Matuku Island; one in talo was negative for mosquitoes and the other in *Pandanus* was positive for both *tongae tongae* and *oceanicus.* Matuku is a small uplifted limestone island, southwest of Ha'afeva (Map V). He made 3 additional leaf axil collections on Tofua, a large volcanic island to the west (Map V), all positive for mosquitoes; one in talo with only *oceanicus* and 2 from *Pandanus*, one with only *tongae tongae* and one associated with *oceanicus.* Even though the sample size was also small it is interesting that the 3 *Pandanus* leaf axil collections had *tongae tongae.* Like *kesseli* and *cooki* on Vava'u, *tongae tongae* has so far been collected only from *Pandanus* leaf axils and with the other 2 species only in paongo *(P. whitmeeanus).* It would be of interest to know whether the *Pandanus* leaf axil collections from Matuku and Tofua islands were also only from paongo. Of the natural immature habitats, 10.9% were negative for mosquitoes and 73.4% were positive for *tongae tongae.* Two of the 4 samples from artificial containers (a large whale oil boiler and a bucket found in the bush) contained *tongae tongae.* There are relatively few types of immature habitats available on the low and usually small coral islands of the Ha'apai group. Accumulations of ground water are few and scattered, while the nearest volvanic rock holes occur on Tofua and Kao islands far to the west and no coral rock holes were observed on the islands surveyed. Crab holes may provide sites for *tongae tongae*, however the biting densities encountered during the study do not suggest profuse crab hole populations. The smaller uninhabited islands are dominated by coconut trees, plus scattered native trees and shrubs and very few introduced *Pandanus* and talo plants. Consequently, tree holes and coconuts (coconut - split, drinking and rat-eaten and coconut spathes), provided the only niches for *tongae tongae* with *oceanicus* occurring if there are suitable leaf axils available. The lack of standing water on most small islands precludes the presence of *Ae. vexans, Cx. annulirostris* and *Cx. sitiens.*

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[1]Lifuka (30), Uiha (13), Foa (2), Kauvai Ha'ano (4), the 9 uninhabited islands of Limu (3), Luahoko (2), Luangahau (2), Nukunamu (2), Tatafa (2), Tofanga (2), Uanukunahake (1), Uanukuhihifo (2), and Uoleva (3).

[2]Ramalingham, S. (1965). The mosquito fauna of Samoa and Tonga and its relation to subperiodic Bancroftian filariasis. Univ. Calif., Los Angeles, Ph.D. dissertation, 172 p.

The 24 immature collections made in 1963 by Ramalingham, (8 on Matuku Island, 5 positive and 16 on Tofua Island, 14 positive), appear to be the only other site collections made in Ha'apai. The collections were: 11/14 tree holes, *tongae tongae*; 2/4 coconuts, *tongae tongae;* 1/2 leaf axils (talo), *oceanicus*; 3 leaf axils *(Pandanus)*, 1 *tongae tongae*, 2 *tongae tongae* and *oceanicus;* and 1 ground pool, *vexans.*

Relative abundance of tongae tongae *in aquatic habitats.* Based on the subsamples taken, 55.1% of all sites positive for *tongae tongae* were rated abundant, 12.2% common and 32.7% few (Table 7). Lifuka and Uiha islands have been separated from the other islands since they represent inhabited and larger islands which have more diverse habitats. On Lifuka and Uiha islands, 83.1% of the collections were positive for mosquitoes, 66.7% of those were positive for *tongae tongae* whereas all 25 of the collections made on the other islands were positive for *tongae tongae*. The relative abundance of *tongae tongae* in the first group was equally split between abundant (41.7%) and few, while it was 68.0% abundant and 24.0% few in the 2nd group. Large tree holes provided 4 times as many abundant as few (12:3) while small tree holes had twice as many few as abundant (6:12). All coconuts positive for *tongae tongae* were abundant and 2/3 coconut spathes sampled provided abundant immatures of *tongae tongae*. The highest number of immatures/sample came from: the tree hole in a fallen tava (*Pometia pinnata* Forster) on Lifuka (142), closely followed by a split coconut on Uanukulihifo (141), a plastic bucket from the bush (121), and a coconut spathe on Tatafa (118). Sample counts ranged from 1 to 142 immatures/positive collection for *tongae tongae*. The average number/ positive collection was 35.6 (1672/47). The average, median and range for each of the types of natural immature habitats were: tree holes 23.9 (908/38), 15, 1-97, (small, 10.7 (214/20), 5, 2-29), (large, 38.6 (694/18), 26, 1-97); fallen tree, 96.5 (193/2), -, 51-142; coconut, 88.3 (353/4), 77, 58-141; and coconut spathes 72.7 (218/3), 90, 10-118.

Immature habitat preference. The basic immature habitat for *tongae tongae* on the low islands in Ha'apai is the tree hole. Forty out of 44 collections (90.9%) were positive for *tongae tongae* (included also are the 2 fallen tree collections). Fallen plant parts, i.e. coconut and coconut spathes provided the only other numerous and productive immature collections. The biomass of *tongae tongae* produced at the time of the study was probably also in that order. Artificial containers were relatively insignificant at the time but will no doubt increase in number and diversity and become more important, especially on the inhabited islands.

Mosquito species composition at larval habitats. Species other than *tongae tongae* were collected on only 14 occasions (Table 8). Of the 61 collections positive for Culicidae: 49 contained *tongae tongae*, 5 *aegypti*, 3 *Cx. quinquefasciatus*, 4 *oceanicus*, 3 *vexans* and 2 *Cx. annulirostris*. No *Cx. sitiens* were found. *Aedes tongae tongae* was the only species in 47 collections and it was associated with other species of mosquitoes in only 2 samples; with *aegypti* in a large tree hole at the base of a mango in Pangai village, at a 3.5:1 ratio; with *aegypti* and *Cx. quinquefasciatus* in a large whale oil boiling pot (diameter 1.2 m) at a ratio of 1:61:10. *Aedes aegypti* was abundant and was the only species found in a cistern; it was associated with *Cx. quinquefasciatus* in a whale oil boiling pot and a coconut shell used to dip water from the pot (8 *aegypti*: 4 *Cx. quinquefasciatus*). *Aedes oceanicus* was identified in 4/5 leaf axil collections, 2 kape (giant talo) and 2 *Pandanus* (paongo and tofua); the negative sample was derived from talo. It was abundant in 3 of the 4 collections, being few in the paongo sample. *Aedes vexans* was sampled from a grassy depression and 2 flooded forest situations, one permanent and the other semipermanent. The latter had dense undergrowth and emergent vegetation of a terrestrial nature, indicating recent flooding. *Culex annulirostris* was taken on 2 occasions from permanent ground pools, one, a limestone sink 4.9 x 6.1 m and 0.3-0.6 m deep with leaves covering the mud bottom in partial and deep shade. The other was a pond with a diameter of 23 m, filled with leaves and stems in

TABLE 7. Immature habitats sampled and the relative abundance of *Aedes tongae tongae* by category.

Immature habitat category	Lifuka and Uiha islands						Other islands (11)						Total					
	Number collected	Negative for mosquitoes	Positive for *Ae. t. tongae*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. t. tongae*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. t. tongae*	A	C	F
Ground pool	6	1	0	-	-	-	0	0	0	-	-	-	6	1	0	-	-	-
Tree hole (Small) (Large)	22 (14) (8)	4 (3) (1)	18 (11) (7)	6 (3) (3)	3 (1) (2)	9 (7) (2)	20 (9) (11)	0 (0) (0)	20 (9) (11)	12 (1) (11)	2 (1) (1)	6 (5) (1)	42 (23) (19)	4 (3) (1)	38 (20) (18)	18 (6) (12)	5 (2) (3)	15 (12) (3)
Fallen tree	2	0	2	2	-	-	0	0	0	-	-	-	2	0	2	2	-	-
Coconut	3	1	1	1	-	-	3	0	3	3	-	-	6	1	4	4	-	-
Coconut spathe	1	0	1	-	1	-	2	0	2	2	-	-	3	-	3	2	1	-
Leaf axil	5	1	0	-	-	-	0	0	0	-	-	-	5	1	0	-	-	-
Subtotal natural sites	39	7	22	9	4	9	25	0	25	17	2	6	64	7	47	26	6	15
Artificial container (Large)	4	0	2	1	-	1	0	0	0	-	-	-	4	0	2	1	-	1
Total	43	7	24	10	4	10	25	0	25	17	2	6	68	7	49	27	6	16

A = abundant, 20+; C = common, 10-19; F = few, 1-9 immatures per sample.

TABLE 8. Mosquito species composition at immature habitats.

Species	Total	Ilifuka and Uiha	Other islands (11)
(No mosquitoes found)	(7)	(7)	(0)
Ae. tongae tongae only	47	22	25
Ae. tongae tongae with *Ae. aegypti*	1	1	0
Ae. tongae tongae, Ae. aegypti and *Cx. quinquefasciatus*	1	1	0
Ae. aegypti only	1	1	0
Ae. aegypti with *Cx. quinquefasciatus*	2	2	0
Ae. oceanicus only	4	4	0
Ae. vexans only	3	3	0
Cx. annulirostris only	2	2	0
Total	68	43	25

direct sun. It is of interest that *vexans* and *Cx. annulirostris* were not associated in any of the last 4 sites.

Invertebrate fauna associated with mosquito larval habitats. Sixty-five of 68 aquatic sites sampled (95.6%) provided invertebrate specimens including: 61 (89.7%) positive for Culicidae and 49 (72.1%) for *tongae tongae*. Forty-seven (69.1%) provided invertebrates other than mosquitoes, with only 4 collections in which non-Culicidae were the only invertebrates recovered. The remaining 43 collections were all associated with mosquitoes. Table 9 gives a breakdown of the various categories of invertebrates recovered by type of habitat. The only non-arthropods of importance were the phylum Mollusca (all snails), with 13 samples (19.1%) including: ground water (3/6), tree holes (7/42) (2 small and 5 large), coconuts (2/6), and coconuts spathes. Pond snails were found in a pond on Uiha (3.7 x 3.7 x 1.2 m) which was apparently dug into the water table for watering plants, there were no Culicidae present but predaceous diving beetles and Notonectidae were recorded. Pond snails were also collected from 2 ground pools on Lifuka in association with *Cx. annulirostris* and various other arthropods. Interestingly, with the exceptions of Uiha and Lifuka, pond snails have been recovered only on Tongatapu. Two Annelida (Oligochaeta) were collected from a talo leaf axil and were not with any other invertebrates. Crustacea (*Daphnia* sp.) were sampled in 3 large tree holes - all were from man-made reservoirs, in the base of coconut trees, called "haka" used for drinking water for people and horses. Surface mites (Acarina) were sampled from 3 tree holes and 2 split coconuts. The non-dipterous insects included: Collembola-one sample from a large tree hole on Uoleva with *tongae tongae*, Ceratopogonidae and Psychodidae; Odonata-3 samples, a large tree hole in the base of an ifi tree (*Inocarpus edulis* J. R. and G. Forster) with an Anisoptera naiad (Libellulidae), Veliidae and no Culicidae, both Anisoptera and Zygoptera naiads were observed in 2 ground pools with *Cx. annulirostris*, pond snails, Veliidae, Notonectidae and, in one pond, diving beetles; aquatic Hemiptera were recovered in 4 samples and represented

TABLE 9. Invertebrate fauna found associated with mosquito larval habitats.

Taxa	Ground pool, etc.	Artificial container	Tree hole (small)	Tree hole (large)	Fallen tree	Coconut	Coconut spathe	Leaf axil	Total
Number of collections	6	4	23	19	2	6	3	5	68
(With associated invertebrates)	6	4	20	19	2	6	3	5	65
(With associated invertebrates, non-Culicidae)	3	-	19	18	1	4	1	1	47
Mollusca	3	-	2	5	-	2	1	-	13
Annelida	-	-	-	-	-	-	-	1	1
Arthropoda									
Crustacea	-	-	-	3	-	-	-	-	3
Arachnida	-	-	2	1	-	2	-	-	5
Insecta									
Collembola	-	-	-	1	-	-	-	-	1
Odonata	2	-	-	1	-	-	-	-	3
Hemiptera	3	-	-	1	-	-	-	-	4
Coleoptera	3	-	-	-	-	-	-	-	3
Diptera	5	4	20	18	2	6	3	4	62
(Diptera, excluding Culicidae)	-	-	18	17	1	2	-	-	38
Diptera									
Tipulidae	-	-	-	1	-	-	-	-	1
Psychodidae	-	-	3	3	-	-	-	-	6
Chironomidae	-	-	-	1	-	-	-	-	1
Ceratopogonidae	-	-	18	16	1	-	-	-	35
Culicidae	5	4	20	18	2	5	3	4	61
Cecidomyiidae	-	-	-	-	-	2	-	-	2

Notonectidae and Veliidae, both on 3 occasions, twice in the aforementioned ground pools with *Cx. annulirostris*, etc., and Notonectidae in the pond on Uiha, while the Veliidae were with the Anisoptera naiad in the tree hole; Coleoptera (Dytiscidae and/or Hydrophilidae)-2 samples, with pond snails and Notonectidae on Uiha and in a ground pool with *Cx. annulirostris* on Lifuka.

Non-culicid Diptera associated with tongae tongae. Thirty-eight of the aquatic sites (55.9%) sampled had non-culicid Diptera, only one of which did not contain *tongae tongae* (a split coconut from Uiha harbored only Cecidomyiidae (51 larvae)). With the exception of the 2 samples from coconuts with Cecidomyiidae (*Resseliella* sp.) all non-culicid dipterous larvae were sampled in tree holes including the tree hole in a fallen tava (*Pometia pinnata* Forster) on Lifuka. Of the 42 tree holes plus the 2 tree holes in fallen trees 81.8% (36/44) had non-culicid dipterous larvae associated with *tongae tongae* and on one occasion in association with *tongae tongae* and *aegypti*, in a tree hole at the base of a mango with the ubiquitous ceratopogonid, *D. hitchcocki*.

Tipulidae were recovered in one sample from the "haka" in the base of a coconut tree in association with *Daphnia* sp., this was the only positive sample that did not also include *D. hitchcocki*.

Chironomidae (*Chironomus* sp.) were collected only once, in a large tree hole in puko (*Hernandia ovigera* Linnaeus) on Lifuka, with both ceratopogonids and snails.

Psychodidae (*Telmatoscopus* sp. probably *vitiensis*) were sampled on 6 occasions always with *tongae tongae* and *D. hitchcocki* on Uiha, Kauvai - Ha'ano, Foa, Uoleva and Lifuka, in 3 large and 3 small tree holes, once also in association with Collembola and another also with snails.

Ceratopogonidae, all *Dasyhelea hitchcocki*, were included in 35 of the 38 collections positive for non-culicid Diptera (92.1%) and 79.5% (35/44) of all tree holes. They were collected on all islands surveyed, in all instances with *tongae tongae* and on the occasions cited above with *aegypti*.

Biting activity. Biting-landing collections of *tongae tongae* were made on 8 of the 13 islands surveyed (15 collections) between 0745-1615 h. The highest densities encountered were on Kauvai - Ha'ano in 3 collections, all in shade under trees: 2.8/min (1100-1110 h) November, 2.4/min (0800-0820 h) August 2, 2.4/min (0820-0840 h) August; and one on the east side of Lifuka under a mango tree, 2.8/min (1020-1030 h) November. Two other collections were in excess of 2/min : Luahoko in shade under a puka tree, amid hundreds of nesting noddy terns (*Anous* sp.), 2.1/min (0900-0910 h), and the north end of Lifuka in a coconut plantation with manioke (*Manihot esculenta* Crantz) and tall grass, 2.2/min (1000-1010 h). Only 3 collections were less than 1.0/min. At what appeared to be a "good" biting habitat on Uiha, only 2 biting-landing females were encountered (0.03/min), in an hour of collecting, this, in spite of the fact that numerous males utilized the collector's head as a swarming marker. One biting-landing female was captured indoors at 1615 h. Almost half of the biting-landing collections provided males (6/15); one collection from Luangha contained only males (1400 h, native trees and bush, partial shade). The males had a landing rate of 1/min and many were swarming above and around the head. On Liumu (0930-0940 h) the biting-landing rate for females was 1.3/min while the landing rate for males was 0.7/min. Copulation was observed on Limu - the swarming marker being the top of the head, the union was initiated 10 cm above the head and the adults in copula dropped to the hair, they separated and departed in 10 to 20 seconds. On Tofanga Island (0745-0755 h), 12 male and 17 female *tongae tongae* were captured, 1.2 and 1.7/min. The use of the human head as a swarming marker has been observed in all areas surveyed in the

Tonga area, but not to the extent observed with *tongae tongae* at the time of the survey, and likewise the male landing rates were insignificant in all other areas studied. Ramalingam* made 5 biting-landing collections in the Ha'apai group of which 2 were positive for *tongae tongae:* a plantation and bushes on Matuku (1500-1700 h); and on Tofua in a hut in the bush at an elevation of 400 feet (120 m) (0900-1100 h). The other 3 collections were at night; in a home on Nomuka Island (southern Ha'apai - Map V) at 2000-2130 h - *Cx. annulirostris;* Matuku - house (2100 h) *oceanicus;* and Tofua - hut (2100 h) *oceanicus* and *Cx. annulirostris.* A request was made to catch some mosquitoes in the Palace at Pangai on Lifuka, since so many mosquitoes were biting during the day. All captured were *aegypti,* the primary sources being the whale oil boiling pot, roof gutters and a cistern.

Fecundity. Fifty-nine egg batches (3,901 eggs) were deposited by *tongae tongae* ranging from 20 to 113 eggs per female, with a mean of 66.1 and a median of 68. Two groups of eggs were studied, 41 batches from August 1973 and 18 from November 1971. These groups have been separated to demonstrate the relative fecundity at different times of the year. The adults were captured, in a similar ecological setting, within 0.8 km of each other, on Kauvai-Ha'ano Island. The winter-spring population of relatively robust, August 1973, females had the highest frequency in the 90-99 clutch size (7/41) closely followed by the 80-89 clutch size (6/41) with 41.5% of the egg batches 80 or more with 53.6% (22/41) in excess of 70 per female. The corresponding frequency distribution for the summer population (November 1971) was in the 50-59 (4/18) and 60-69 (4/18) clutch sizes with only 27.8% (5/18) of the females laying more than 70 eggs. The mean clutch sizes were 66.3 (2,720/41) and 65.6 (1,181/18) with corresponding median batches of 73 and 60 per female in ranges of 20-113 and 28-106.

Fertility. Progeny rearings derived from *tongae tongae* collected and fed on Kauvai-Ha'ani Island and reared on Tongatapu provided data on the "effective fertility" based on survival to 4th stage larvae. The overall "effective fertility" rate from 6 females was 90.4% with 431 of 477 eggs hatching and surviving to at least 4th stage larvae. The rates for the individual females were: 73.5% (36/49), 87.7% (93/106), 90.3% (84/93), 92.0% (81/88), 95.9% (70/73) and 98.5% (67/68).

Gonotrophic cycle. The length of time from blood feeding to commencement of oviposition was determined for 28 *tongae tongae* in Pangi, Lifuka for November-December 1971. The females were fed at 1600 h on 30 November with oviposition commencing on 2 December at 1000 h (66 hours) and the last female ovipositing by 1800 h (98 hours), on 3 December. The average oviposition was 77.7 hours with 50% of the females commencing oviposition between 72 and 74 hours (72 h 1600, 5; 73 h 1700, 3; 74 h 1800, 6). An additional 5 oviposited between 76 and 80 hours (2000-2400) another 4 between 81-85 hours (0100-0500) and 3 by 88.5 hours (0830). 65.9% oviposited during the 8 hours from 72-80, 82.1% during the 12 hours following 72, and 92.9% (26/28) during day 4, i.e. 72-96 hours post blood meal. A seasonal difference was also observed in the length of the gonotrophic cycle of *tongae tongae* with an increase in length among the winter-spring population as compared to the summer population. Unfortunately, the data have been complicated and compounded by the fact that the Ha'apai caught and fed (0900 h 9 August 1973) females were transported to Tongatapu on the following day, where the average temperatures are usually 2-3^{o} C cooler than in Ha'apai. Of the 44 females

*Ramalingam, unpublished Ph.D. thesis, l.c.

under observation, only 2 (4.5%) commenced oviposition, on day 4 (as compared to 92.9% in the summer population), while 35 (79.5%) oviposited on day 5, 5 on day 6 and 1 on day 7.

Autogeny. *Aedes tongae tongae* was also found to be autogeneous in a colony developed from eggs derived from the 1971 study.

MEDICAL IMPORTANCE. *Aedes tongae tongae* is the suspect vector of subperiodic *W. bancrofti* and dengue-1 and dengue-2 viruses. It also probably transmits *D. immitis*.

Filariasis. Unfortunately, *tongae tongae* remains a suspect vector of *W. bancrofti* since no dissections have been made for naturally infected specimens. We made a parasitological and clinical survey of Koulo village and some people in Pangai on Lifuka Island for filariasis in August 1973.* The overall microfilaria rate for 309 villagers of all age groups was 51.5% by the membrane filter concentration technique (MFC). This rate would calculate to 20.4% by the usual 60 cmm blood film technique. These figures include 172 people (55.7%) under 20 years of age, including 82 (26.5%) less than 10 years. The microfilaria rates for the sample 20 years and over was 62.8% (86/137) by MFC which would calculate to 32.8% (45/137) by 60 cmm blood film. The microfilaria rates characterize an area of very high endemicity, with abundant and efficient vectors of *W. bancrofti*. *Aedes oceanicus* is present and a confirmed vector in Tonga (Hitchcock 1971), however, the high endemicity shown suggests that *tongae tongae*, the only member of the *scutellaris* group present in Ha'apai, is not only a suspect vector but probably the major vector of subperiodic *W. bancrofti* in the Ha'apai group. Although no data are available on *D. immitis*, is more than likely present and probably transmitted by *tongae tongae*.

Dengue. Cases of dengue-like illness were reported from Ha'apai during both the dengue-2 outbreak of 1974 and the dengue-1 outbreak of 1975. *Aedes aegypti*, a known vector of dengue, is present, but of spotty distribution. Consequently, *tongae tongae* may have also played a role in transmission, as has been suggested for other members of the *scutellaris* group, and should be considered a suspect vector of dengue.

AEDES (STEGOMYIA) TONGAE TABU RAMALINGAM AND BELKIN (Figs. 10, 11, 12, 13, 14, 15, 16)

Aedes (Stegomyia) tongae of Belkin 1962: 475 (♂*, ♀, P*, L*, in part).
Aedes (Stegomyia) tabu Ramalingam and Belkin 1965: 1 (♂*, ♀, P*, L); Ramalingam 1976: 306 (biology).

As in *cooki* except for:

MALE. *Head*. Proboscis dark scaled, with some pale scales on the ventral side, slightly longer than forefemur. *Thorax*. Scutum with median stripe usually rather narrow from anterior margin, narrows slightly posteriorly and forks at beginning of the prescutellar space; prescutellar line and posterior dorsocentral line usually distinct, well developed, with narrow yellowish pale scales; the apical dark spot of midlobe rather small; lower mesepimeral scale patch of medium or large size and separated from, or sometimes narrowly connected to, the upper mesepimeral scale patch. *Legs* (Fig. 16). Hindfemur anteri-

*Unpublished data, but combined with Te'ekiu village, Tongatapu in Desowitz et al. 1976.

orly with a rather narrow median white longitudinal stripe which widens at basal 0.25-0.40 and is separated from apical white scale patch; fore- and mid-tarsi with basal white bands on tarsomeres 1,2; hindtarsus with basal white bands on tarsomeres 1-4, the ratio of length of white band to the total length of tarsomere is 0.33, 0.33, 0.40 and 0.40-0.60; tarsomere 5 all white, or sometimes with a few dark scales at tip on ventral side; sometimes hindtarsus with basal white band on tarsomere 4 interrupted by a few dark scales on ventral side as well, or basal white bands on tarsomeres 4,5 interrupted by a stripe of dark scales on ventral side. *Abdomen*. Fig. 14). Segment I with white scales on laterotergite, or sometimes with a median pale spot as well; tergum II with a distinct median white spot and with lateral white spots, or sometimes tergum II dark dorsally, with lateral white spots only; terga III-VI each with a complete sub-basal transverse pale band and with lateral white spots which are connected to the tergal band; tergum VII varied, with lateral white spots only or with a sub-basal median spot as well, or with sub-basal transverse complete or dotted band. *Terminalia* (Figs. 10, 13). Claspette simple, slender, sternal and tergal sides parallel, apical 0.33 usually slightly upturned and a basosternal angle present in lateral aspect (dissected claspette), usually with 6 or 7 modified setae in a row on apical 0.20-0.25 of sternal side, lateral surface with setae extending basad to 0.28-0.40 of the entire claspette length; the modified setae rather stout and distinct; apex tergally with setae about 0.50 as long as entire claspette length.

FEMALE. Essentially as in the male, differing in the following respects: *Head*. Palpus with white scales on apical half or more. *Thorax*. Apical dark spot of midlobe sometimes large. *Abdomen* (Fig. 15). Terga III-VI usually with complete or dotted sub-basal transverse pale bands and connected to the lateral white spots; sometimes tergum VI with a sub-basal median pale spot and with lateral white spots which are turned dorsomesally; rarely tergum VI with lateral white spots only; rarely terga III-VI each with a median pale spot and lateral white spots which are turned dorsomesally; tergum VII varied, as in the male. *Terminalia* (Fig. 12). Insula with minute setae and with 6 larger ones on apical 0.4; tergum IX with well-developed lateral lobes, each with 5 (4-6) setae.

PUPA (Fig. 10). *Cephalothorax*. Trumpet about 3.8 as long as wide at the middle; seta 1-C usually single, about length of 3-C, 3-C single, long, 4-C usually double (1,2), 5-C usually double (1-3), 7-C usually double (1,2), 8-C usually 4-branched (2-8), 10-C usually 4-branched (2-6), 12-C usually single (1,2). *Abdomen*. Seta 1-II with 4-16 branches; 1-III usually double (1-5); 1-IV usually single (1,2); 5-IV-VI usually single, or sometimes 5-IV, V double, usually short, not reaching beyond posterior margin of following segment; 9-VI, VII usually single, stout and barbed, or sometimes 9-VI, VII double, much stouter and longer than preceding ones; 9-VIII usually with 3 main stems (2-4), and lateral branches of varying length.

LARVA (Fig. 11). *Head*. Seta 7-C usually 3-branched (2,3), 10-C usually double (1,2), 12-C double, 13-C usually single (1,2), mentum with 10,11 teeth on each side. *Thorax*. Seta 1-P usually 3-branched (2,3), 4,7-P usually double (2,3), 14-P usually with 3,4 branches; 9-M usually 3-branched (2,3); 7-T usually with 4-7 branches. *Abdomen*. Seta 6-I usually 4-branched (3-5), 6-II usually 3-branched (3-5), 7-II usually 2-branched (2,3); 6-III-V usually double; 6-VI usually single (1,2); 1-VII usually 3-branched (2-4), 2-VII usually single (1,2); 5-VIII usually with 3,4 branches; comb of 8-14 scales, in a single row, each scale with fine denticles at the base of the apical spine, sometimes comb scale with apical spine split at tip; seta 2-X usually with 2,3 branches,

sometimes 4-branched, 3-X single; ventral brush with 4 pairs of setae on grid, 4a,b-X usually single (1,2), 4c,d-X usually double (2,3), anal papillae 2.5-3.0 length of saddle. *Siphon.* Short, about 2.0-2.6 as long as wide, pecten teeth 8-18, evenly spaced, each tooth usually with one large and one small basal denticle.

TYPE-DATA. *Aedes (Stegomyia) tabu* Ramalingam and Belkin, holotype male (234-25) with associated larval and pupal skins and terminalia on a slide, allotype female (235-26) with associated larval and pupal skins, in USNM; type-locality: Eua Island, Tonga, 17-VI-1963 (S. Ramalingam). Paratypes: 1 male (223-102) with associated pupal skin, 14-VI-1963, 1 whole larva (235), 17-VI-1963, in BMNH; 1 female (228-101), 1 male (228-102) with associated pupal skins, 15-VI-1963, 1 male (234-101) with associated pupal skin, 2 whole larvae, 1 male (235-109) with associated pupal skin, 1 whole larva (235), 17-VI-1963, in (UCLA); 1 male (235-3), 1 whole larva (235), 17-VI-1963, in University of Queensland, Brisbane, Australia, 1 whole larva (235), in USNM. All specimens from Eua Island, Tonga, collected by S. Ramalingam.

DISTRIBUTION. This subspecies is presently known only from the Tongatapu Group of Tonga (Map VI).

1,482 specimens examined: 204♂, 158♀, 86♂ terminalia, 5♀ terminalia, 241 L, 405 individual rearings (383 l, 405 p).

TONGA. *Tongatapu Group*: *Pangaimotu Island.* (X-1973 progeny rearings in SEAMP), 104♂, 108♀, 24♂ terminalia, 92 L, 254 individual rearings (254 l, 254 p); *Tongatapu Island,* Nuku'alofa, (VII-1972 individual rearings), 18♂, 15♀, 6♂ terminalia, 14 L, 35 individual rearings (13 l, 35 p); (III-1925, G. H. E. Hopkins), 2 L; Hofoa, (V-VI-1963, UCLA collection), 4♂, 4♂ terminalia, 26 L; Houma, (V-VI-1963, UCLA collection), 4♂, 4♂ terminalia, 2 L; Matahau, (V-VI-1963, UCLA collection), 4♂, 4♂ terminalia, 9 L; *Eua Island,* (I-1974 progeny rearings in SEAMP), 48♂, 34♀, 22♂ terminalia, 4♀ terminalia, 81 L, 114 individual rearings (114 l, 114 p); (VI-1963, S. Ramalingam), 1♂, 1♀, 1♂ terminalia, 2 individual rearings (2 l, 2 p); (V-VI-1963, UCLA collection), 21♂, 21♂ terminalia, 1♀ terminalia, 15 L.

TAXONOMIC DISCUSSION. *Aedes tongae tabu,* a member of the *scutellaris* group, is extremely similar to other members of the group in the Tonga islands. The females have stronger white abdominal bands than those of *cooki* and *kesseli* and approach the condition in that of *tongae tongae.* The male terminalia are very similar to those of *tongae tongae,* but the setae on the lateral surface of the claspette are more extensive. However, this is not always a reliable character, for there is considerable variation in *tongae tabu,* as well as in *tongae tongae,* as indicated in the key.

The pupa is extremely similar to those of *polynesiensis, cooki* and *tongae tongae* in seta 9-VI, VII usually single, stout, and barbed, or forked at the tip. It is indistinguishable from those of *polynesiensis* and *tongae tongae* but can be distinguished from that of *cooki* by the seta 5-IV, V which is usually single.

The larva is very similar to that of *pseudoscutellaris* but can easily be distinguished by the branched condition of seta 5-M. It is also very similar to those of *cooki* and *tongae tongae* but can be distinguished by the setae 4a,b-X which are usually single (1-2). In *cooki,* the setae 4a,b-X are usually 3-branched (2-4); in *tongae tongae,* 4a,b-X are usually double (1,2).

Aedes tongae tabu is evidently most closely related to *tongae tongae* from Ha'apai. *Aedes (Stegomyia) tabu* was originally described by Ramalingam and Belkin (1965: 1) as a distinct species from Eua Island. The present studies indicated that there are no clear-cut differences in all stages of these 2 forms and that *tabu* does not occur in the Ha'apai Group where *tongae* is the dominant

form. This evidence suggests that these 2 forms are only subspecifically distinct.

Ramalingam and Belkin (1965: 2) mentioned that both hairy and nonhairy larvae are known.

At the present time *tongae tabu* is the only known member of the *scutellaris* group on the Tongatapu Group (Pangaimotu, Tongatapu, Eua), in the Tonga islands.

BIONOMICS. *Aedes tongae tabu* is a common diurnal man-biting species, expecially abundant on the uninhabited islands near Nuku'alofa where there are numerous crab holes. It is abundant in the bush, common in villages and like *cooki* and *kesseli* is not infrequently found biting in houses. It is a confirmed vector of *W. bancrofti* and was also found naturally infected with *D. immitis*. *Aedes tongae tabu* was infected with dengue-2 and is a suspect vector of dengue-1 virus. Field studies were made in the Tongatapu group between 1972 and 1975. Unlike the other species and subspecies, i.e. *cooki*, *kesseli* and *tongae tongae*, significant work was done on *tongae tabu* prior to our studies. The work by Dr. Shivaji Ramalingam during May and June of 1963 resulted in the description of *tabu* (Ramalingam and Belkin 1965), its incrimination as a vector of *W. bancrofti* by both natural and experimental infections (Ramalingam and Belkin 1964, 1965; Ramalingam*), and important data on its bionomics (Ramalingam*, 1968, 1976). Some of his data have been summarized for comparison. Besides extending his findings, our work has also contributed some new and significant data.

Immature habitats. Two hundred and nineteen sites were surveyed for immature mosquitoes in the Tongatapu group during the study. Of these, 146 (66.7%) were positive for mosquitoes with 43.8% positive for *tongae tabu* (Table 10). *Aedes tongae tabu* were collected in: tree holes, coconuts, a coconut spathe, leaf axils of a giant talo, giant clam shells, and artificial containers. Seventy-three samples (33.3%) did not contain mosquitoes and 40 samples which provided mosquitoes were not found with *tongae tabu*. There was a predominance of artificial habitat samples (67.6%). This is primarily accountable to two dengue outbreaks which occurred on Tongatapu in 1974 and 1975 which resulted in 4 village larval surveys and additional peridomestic surveys in the premises of suspected dengue cases. The majority of immature habitats in the peridomestic environment are man-provided; which includes all artificial containers as well as many coconut shells, decorative giant clam shells and even leaf axils. Since almost two-thirds of the kingdom lives on the 254 km^2 Tongatapu Island (an estimated 1974 population of 63,000 of 95,000), peridomestic habitats, especially artificial ones, provide significant man-mosquito contact. Thus the numerous artificial habitats sampled may be proportionally valid. Table 10 also gives a summary of the important collections made by Ramalingam (unpublished Ph.D. thesis, l.c.) in 1963. Although all ground pools sampled were positive for mosquitoes, none contained *tongae tabu*. All tree holes positive for mosquitoes had *tongae tabu*, however, more than 50% of the small tree holes were negative. Immature *tongae tabu* occurred in 68.6% of the coconut shells sampled, however, of the 29 recorded by type, *tongae tabu* was in only 10/17 split coconuts (one additional nut had *Cx. quinquefasciatus* only) while it was found in 8/10 drinking nuts and 2/2 rat-eaten coconuts. Only one coconut spathe was sampled and positive (Ramalingam

*Ramalingam, S. 1965. The mosquito fauna of Samoa and Tonga and its relationship to subperiodic Bancroftian filariasis. Ph.D. thesis, Univ. of California, Los Angeles. 172 p.

TABLE 10. Immature habitats sampled and the relative abundance of *Aedes tongae tabu* by category (including a summary of Ramalingam's 1963 collections)*.

Immature habitat category	Tongatapu group						Tongatapu group (Ramalingam)			Total		
	Number collected	Negative for mosquitoes	Positive for *Ae. tongae tabu*	A	C	F	Number collected	Negative for mosquitoes	Positive for *Ae. tongae tabu*	Number collected	Negative for mosquitoes	Positive for *Ae. tongae tabu*
Ground pools	8	0	0	-	-	-	10	2	0	18	2	0
Tree hole	20	9	11	3	4	4	11	1	10	31	10	21
(Small)	(16)	(9)	(7)	(1)	(4)	(2)	(9)	(1)	(8)	(25)	(10)	(15)
(Large)	(4)	(0)	(4)	(2)	(-)	(2)	(2)	(0)	(2)	(6)	(0)	(6)
Coconut	35	10	24	17	4	3	3	0	3	38	10	27
Coconut spathes	1	0	1	1	-	-	1	0	1	2	0	2
Leaf axil	3	1	1	-	-	1	21	1	10	24	2	11
(Giant talo)	(2)	(0)	(1)	(-)	(-)	(1)	(7)	(0)	(3)	(9)	(0)	(4)
(Talo)	(0)	(0)	(0)	(-)	(-)	(-)	(9)	(0)	(7)	(9)	(0)	(7)
(Pandanus)	(0)	(0)	(0)	(-)	(-)	(-)	(5)	(1)	(0)	(5)	(1)	(0)
(Palm)	(1)	(1)	(0)	(-)	(-)	(-)	(0)	(0)	(0)	(1)	(1)	(0)
Clam shell	4	2	2	-	-	2	2	0	0	4	2	2
Subtotal natural sites	71	22	39	21	8	10	46	4	24	117	26	63
Artificial container	148	51	57	11	11	35	13	2	3	161	53	60
(Small)	(51)	(28)	(20)	(5)	(4)	(11)	(9)	(0)	(1)	(60)	(28)	(21)
(Large)	(97)	(23)	(37)	(6)	(7)	(24)	(4)	(2)	(2)	(101)	(25)	(39)
Total	219	73	96	32	19	45	59	6	27	278	79	123

A = abundant, 20+; C = common, 10-19; F = few, 1-9 immatures per sample.

*Ramalingam, S. 1965. The mosquito fauna of Samoa and Tonga and its relationship to subperiodic Bancroftian filariasis. Ph.D. thesis, Univ. of California, Los Angeles, 172 p.

also sampled one). *Aedes tongae tabu* was found in 1/2 giant talo with *Ae. oceanicus*. Ramalingam recovered *tongae tabu* in both giant talo and talo, always with *oceanicus;* but it was not recovered in the 4 *Pandanus* collections positive for *oceanicus*. Laird (1956) made a *Pandanus* collection on Tongatapu in 1953 that was positive for *oceanicus* (identified as *samoanus* (Gruenberg)). Giant clam shells *(Tridacna gigas)* are utilized as decorations and borders; although 2/4 sampled provided *tongae tabu,* it is very unusual to find positive shells, even though the shells are abundant and often contain water. Unless there is profuse detritus, the shells do not appear to attract ovipositing females. The majority of shells observed were in direct sun for at least part of the day, and it is possible that the thermal death point was reached often enough to render the niche ineffective for *tongae tabu,* however, those in partial or full shade also seldom contain immature mosquitoes. Artificial larval habitats have been further subdivided in Table 11. Of large containers, only 23.7% were negative for mosquitoes, while 54.9% of the small ones did not provide mosquitoes. Interestingly, those positive for *tongae tabu* were similar in both, i.e. 38.1% and 39.2% respectively. Only 3/35 drums were negative with 57.1% positive for *tongae tabu*. Almost 0.5 of the cisterns were negative (46.1%) and only 3 positive for *tongae tabu*. However, concrete cisterns provided only 8 positive collections (44.4%), with one for *tongae tabu* (5.6%), while 75% of the metal cisterns had mosquitoes, only 25% had *tongae tabu*. Tires were good larval habitats (73.9% positive) with 34.8% positive for *tongae tabu*. Fifty percent of the unused water seal toilets contained *tongae tabu*. Most tin cans were negative for mosquitoes (60%) while 11/12 positive provided *tongae tabu*. The other positive tin can contained only *vexans* - an unusual site for this species.

Relative abundance of tongae tabu *in aquatic habitats*. The overall relative abundance observed for *tongae tabu* (Table 10) of the 96 positive sites was: 33.3% abundant, 19.8% common and 46.9% few. However, 53.8% of the natural aquatic sites were abundant and 25.6% few, while among artificial containers it was 61.4% few to 19.3% abundant. Tree holes provided a relatively even distribution of about 0.33 in each category; however, only 1/7 small tree holes were abundant while 2/4 large tree holes were abundant. The only other significant natural site was coconuts where 70.8% were abundant and only 12.5% were few. The single coconut spathe sampled was, as usual for this niche, abundant. The relatively unexploited niche, provided by giant clam shells, gave few in the 2 rare positives. Between the small and large artificial sites, the small are slightly more favorable in both abundant (25.0% to 16.2%) and few (55.0% to 64.9%). However, if the different major types of artificial sites are examined (Table 11), it is apparent that there are wide differences in their acceptability as immature habitats. Cisterns are very poor sites with concrete cisterns nearly sterile. Only 8/18 concrete cisterns were positive for mosquitoes, one for *tongae tabu,* 2 for *aegypti* and 7 for *Cx. quinquefasciatus*, however in all cases, the samples provided fewer than 10 specimens. Seventy-five percent of the metal water tanks were positive for mosquitoes, 2 for *tongae tabu* and although *tongae tabu* were few, one tank provided abundant *Cx. quinquefasciatus* and one common *aegypti*. Fifty gallon drums commonly used as water storage units and for water seal toilet flush water usually contained mosquitoes (8.6% negative) and provided a mixed group of larvae which were usually few (80.0% *tongae tabu,* 58.6% *aegypti,* 88.9% *Cx. quinquefasciatus*). Occasionally, large absolute numbers occurred, e.g. Te'ekiu village - 99 *tongae tabu* and 132 *Cx. quinquefasciatus,* Lavengatonga village - 30 *tongae tabu* and 188 *aegypti* and Fuamoto village - 34 *tongae tabu* and 205 *aegypti*. Water seal toilet drums, because they are often emptied and disturbed, are not as

TABLE 11. Artificial immature habitats sampled and relative abundance of *Aedes tongae tabu* sampled and major associated species.

Immature larval habitat	Number collected	Negative for mosquitoes	*Ae. tongae tabu*: Positive for *Ae. tongae tabu*	A	C	F	*Ae. aegypti*: Positive for *Ae. aegypti*	A	C	F	*Cx. quinquefasciatus*: Positive for *Cx. quinque-fasciatus*	A	C	F	*Cx. annulirostris*: Positive for *Cx. annulirostris*	A	C	F
Large sites																		
Drum	35	3	20	3	1	16	29	4	8	17	9	1	-	8	1	-	-	1
50 gallon	(26)	(1)	(15)	(3)	(1)	(11)	(23)	(3)	(6)	(14)	(8)	(1)	(-)	(7)	(1)	(-)	(-)	(-)
Water seal toilet	(9)	(2)	(5)	(-)	(-)	(5)	(6)	(1)	(2)	(3)	(1)	(-)	(-)	(1)	(0)	(-)	(-)	(-)
Cistern	26	12	3	-	-	3	7	-	1	6	8	1	-	7	0	-	-	-
Concrete	(18)	(10)	(1)	(-)	(-)	(1)	(2)	(-)	(-)	(2)	(7)	(-)	(-)	(7)	(0)	(-)	(-)	(-)
Metal	(8)	(2)	(2)	(-)	(-)	(2)	(5)	(-)	(1)	(4)	(1)	(1)	(-)	(-)	(0)	(-)	(-)	(-)
Tin (large)	2	0	1	-	1	-	1	-	-	1	2	-	-	1	0	-	-	-
Tire	23	6	8	1	4	3	8	3	1	4	8	2	3	3	1	-	-	1
Miscellaneous	11	2	5	2	1	2	4	2	-	2	3	2	-	1	2	-	1	1
Total (large)	97	23	37	6	7	24	49	9	10	30	30	6	4	20	4	-	1	3
Small sites																		
Water seal toilet	12	5	6	2	1	3	4	-	-	4	1	1	-	-	0	-	-	-
Tin can	30	18	11	2	1	8	0	-	-	-	0	-	-	-	0	-	-	-
Bottle	5	3	1	1	-	-	0	-	-	-	1	-	1	-	0	-	-	-
Miscellaneous	4	2	2	-	2	-	1	-	-	1	0	-	-	-	0	-	-	-
Total (small)	51	28	20	5	4	11	5	-	-	5	1	1	-	-	0	-	-	-
Total (all)	148	51	57	11	11	35	54	9	10	35	31	7	4	20	4	0	1	3

A = abundant, 20+; C = common, 10-19; F = few, 1-9 immatures.

favorable as the usual 50 gallon drum. Tires are widely scattered and excellent sites for all peridomestic mosquitoes. Of those sampled, only 26.1% did not contain larvae, while 34.8% contained each of the 3 common peridomestic species with 12.5% considered abundant in *tongae tabu*, 37.5% in *aegypti* and 25.0% in *Cx. quinquefasciatus*. Unused water seal toilets provided abundant larvae of *tongae tabu* in 2/6, while tin cans gave abundant samples in 2/11. Most artificial sites are not as individually important as natural ones, however, the large number of artificial sites in peridomestic areas at least partially makes up for the rather inefficient production rates. Virtually all the man-produced larval habitats can either be eliminated, modified or moved to reduce peridomestic populations.

Immature habitat preference. There are 4 major natural immature habitats for *tongae tabu* - tree holes, coconuts, leaf axils and crab holes. Although no crab holes were sampled (either in our survey or that of Ramalingam), they are abundant in some of the smaller islands and on areas of Tongatapu where the concurrent mosquito biting rate is relatively high. In some localities, crab holes may be the most important immature habitat for *tongae tabu*, however, in general, the order of preference from our observations is usually coconuts - tree holes - leaf axils. Artificial containers in peridomestic habitats vie for first place with 50 gallon drums at the top of the list. Coconut shells, either split, drinking or rat-eaten are common in the bush and extremely abundant in the village. Quite often there are large heaps of split coconuts related to copra production as well as piles created by domestic use. Drinking nuts and rat-eaten nuts are more common in the bush. The largest absolute numbers of *tongae tabu* were derived from coconuts: a rat-eaten coconut on Pangaimotu provided 152 immatures while a split coconut and a drinking nut in Te'ekiu village provided 102 and 100+ larvae respectively. The positive leaf axil collection provided few larvae of both *tongae tabu* and *oceanicus*. *Aedes tongae tabu*, like *cooki* on Niue, utilizes *Colocasia* leaf axils, however, not as extensively as *cooki* which has no competitor for the niche on Niue. The proportion of *Colocasia* leaf axils with *tongae tabu* in Ramalingam's 1963 collection is significant (10/16 or 62.5%) (Table 10) and has not been shown for any other areas or species under discussion, with the exception of *cooki*, and then only for the Niue population. On the basis of the few collections made from *Pandanus* leaf axils in the Tongatapu group, the utilization of this habitat by *tongae tabu* cannot be eliminated. Further collections, especially from *P. whitmeeanus*, might prove positive. The order of preference of artificial containers were 50 gallon drum followed by unused water seal toilets, tires and tin cans. Concrete cisterns are the least attractive of potential artificial habitats.

Mosquito species composition at larval habitats. Aedes tongae tabu was found in association with other mosquito species in 44 (45.8%) of 96 collections: *aegypti* (33), *oceanicus* (1), *vexans* (1), *Cx. annulirostris* (2), *Cx. quinquefasciatus* (19) and *Cx. sitiens* (1). The species composition of all larval habitats by category is summarized in Table 12. There were 16 combinations of mosquito composition at the sites sampled. Ramalingam found 2 additional combinations during his survey*. In the 146 positive collections for Culicidae: 65.7% contained *tongae tabu*, 38.4% *aegypti*, 27.4% *Cx. quinquefasciatus*, 5.5% *Cx. annulirostris*, 4.1% *vexans*, 1.4% *oceanicus* and 0.68% *Cx. sitiens*.

**Culex quinquefasciatus* and *Cx. sitiens* in a concrete cistern and *tongae tabu* with *Cx. annulirostris* in a 50 gallon drum (Ramalingam, unpublished Ph.D. thesis, l.c.).

One collection contained 5 species: *tongae tabu* > *Cx. annulirostris* > *vexans* > *aegypti* > *Cx. quinquefasciatus.* This unique collection was made from a wash tub in Nuku'alofa within which was a rusted out wash basin that was used as a planter for a fern. Four species were associated in a 50 gallon drum in Longoteme village: *aegypti* > *Cx. quinquefasciatus* > *tongae tabu* and *annulirostris.* Eight collections provided 3 species in association, 7 of which were *tongae tabu, aegypti* and *Cx. quinquefasciatus* all in large artificial containers including 4 times in drums; the 8th was *tongae tabu, Cx. quinquefasciatus* and *Cx. sitiens* associated in a tire. Two species were recovered from the same site on 40 occasions, 8 (20%) of which were from natural sites, including 2 from ground pools, i.e. *vexans* and *Cx. annulirostris,* and *Cx. annulirostris* and *Cx. quinquefasciatus.* The other 6 collections included: *tongae tabu* and *aegypti* in a large tree hole in a mango at Longoteme village, *tongae tabu* and *oceanicus* in the leaf axils of giant talo and 4 *tongae tabu - Cx. quinquefasciatus* associations from Te'ekiu village, 2 in drinking coconuts and 2 in small tree holes. There were also only 8 collections from natural aquatic habitats (excluding ground pools) that provided species other than *tongae tabu* and include the 6 previous sites plus a split coconut with only *Cx. quinquefasciatus* and another leaf axil collection with only *oceanicus.* All other associations were in artificial containers of which drums provided the greatest acceptability (91.4% positive) to numerous species: *tongae tabu* (20), *aegypti* (29), *Cx. quinquefasciatus* (9) and *Cx. annulirostris* (1), all in 32 positive drums. Drums were closely followed by tires (73.9% positive) with 5 species in the 17 positive collections: *tongae tabu* (8), *aegypti* (8), *Cx. quinquefasciatus* (8), *Cx. annulirostris* (1) and *Cx. sitiens* (1). There were 96 collections (65.8% of 146 positive) where only one species was recovered: *tongae tabu* (52), *aegypti* (19), *Cx. quinquefasciatus* (16), *vexans* (4), *Cx. annulirostris* (4) and *oceanicus* (1). *Aedes tongae tabu, aegypti* and *Cx. quinquefasciatus* were found in all categories of large artificial containers. *Aedes tongae tabu* was recovered from all immature site categories cited (16/17) with the exception of ground pools, *Cx. quinquefasciatus* was next with 11/17, closely followed by *aegypti* (9/17), *Cx. annulirostris* was a distant 4th with 4/17, followed by *vexans* (3/17). Of the ground pools, none contained *tongae tabu,* but included were 3 with *vexans* only, 2 with *Cx. annulirostris* only, one with both (*Cx. annulirostris* > *vexans*), one with *Cx. annulirostris* and *Cx. quinquefasciatus,* and a hog wallow with only *Cx. quinquefasciatus.* Ramalingam (unpublished Ph.D. thesis, l.c.) sampled 10 ground pools of which 8 were positive for mosquitoes - 7 with *Cx. annulirostris* only and one, surprisingly, with *aegypti* (muddy bottom in full sunlight on Nuku'alofa), an unusual site for the species. Based on Ramalingam's leaf axil collection, 50% (10/20) of those positive for mosquitoes contained *tongae tabu,* always in association with *oceanicus.*

Invertebrate fauna found associated with mosquito larval habitats. One hundred and sixty-nine of 219 (77.2%) aquatic site collections were positive for invertebrates other than mosquitoes, 23 of which lacked mosquitoes, the remaining 31 being associated with mosquitoes. Table 13 gives the breakdown by recognized group of invertebrate and larval habitat category. Coconuts again provided the most diverse non-culicid fauna for natural habitats including a single collection from a split and fermenting coconut with Ceratopogonidae, Psychodidae, Cecidomyiidae and undetermined cyclorrhaphous larvae. Coconuts also provided *tongae tabu* and *Cx. quinquefasciatus,* both in association and individually. Tin cans provided the most diverse artificial niche with snails, Annelida, Diplopoda, Collembola, Psychodidae, Chironomidae, Cecidomyiidae, cyclorrhaphous larvae and 2 Culicidae (*tongae tabu* and *vexans*

TABLE 12. Mosquito species composition at larval habitats sampled - Tongatapu Group - by larval habitat category.

Species	Natural sites								
	Ground pool	Coconut	Coconut spathe	Tree hole (small)	Tree hole (large)	Leaf axil	Clam shell	Total natural sites	Drum
(No mosquitoes)	(0)	(10)	(0)	(9)	(0)	(1)	(2)	(22)	(3)
T only	-	22	1	5	3	-	2	33	-
T with A	-	-	-	-	1	-	-	1	14
T with A and Q	-	-	-	-	-	-	-	-	4
T with A, V, AN and Q	-	-	-	-	-	-	-	-	-
T with A, AN and Q	-	-	-	-	-	-	-	-	1
T with O	-	-	-	-	-	1	-	1	-
T with Q	-	2	-	2	-	-	-	4	1
T with Q and S	-	-	-	-	-	-	-	-	-
A only	-	-	-	-	-	-	-	-	9
A with Q	-	-	-	-	-	-	-	-	1
O only	-	-	-	-	-	1	-	1	-
V only	3	-	-	-	-	-	-	3	-
V with AN	1	-	-	-	-	-	-	1	-
AN only	2	-	-	-	-	-	-	2	-
AN with Q	1	-	-	-	-	-	-	1	-
Q only	1	1	-	-	-	-	-	2	2
Total by larval habitat	8	35	1	16	4	3	4	71	35
							Summary by species		
Ae. tongae tabu	-	24	1	7	4	1	2	39	20
Ae. aegypti	-	-	-	-	1	-	-	1	29
Ae. oceanicus	-	-	-	-	-	2	-	2	-
Ae. vexans	4	-	-	-	-	-	-	4	-
Cx. annulirostris	4	-	-	-	-	-	-	4	1
Cx. quinquefasciatus	2	3	-	2	-	-	-	7	9
Cx. sitiens	-	-	-	-	-	-	-	-	-

T = *Ae. tongae tabu*, A = *Ae. aegypti*, O = *Ae. oceanicus*, V = *Ae. vexans*,

Artificial sites												
Large						Small						
Cistern (concrete)	Cistern (metal)	Tin (large)	Tire	Miscellaneous (large)	Subtotal	Water seal toilet	Tin can	Bottle	Miscellaneous (small)	Subtotal	Total artificial sites	Total
(10)	(2)	-	(6)	(2)	(23)	(5)	(18)	(3)	(2)	(28)	(51)	(73)
-	1	-	2	2	5	1	11	1	1	14	19	52
-	1	-	2	1	18	4	-	-	1	5	23	24
-	-	1	1	1	7	-	-	-	-	-	7	7
-	-	-	-	1	1	-	-	-	-	-	1	1
-	-	-	-	-	1	-	-	-	-	-	1	1
-	-	-	-	-	-	-	-	-	-	-	-	1
1	-	-	2	-	4	1	-	-	-	1	5	9
-	-	-	1	-	1	-	-	-	-	-	1	1
1	3	-	4	2	19	-	-	-	-	-	19	19
1	1	-	1	-	4	-	-	-	-	-	4	4
-	-	-	-	-	-	-	-	-	-	-	-	1
-	-	-	-	-	-	-	1	-	-	1	1	4
-	-	-	-	-	-	-	-	-	-	-	-	1
-	-	-	1	1	2	-	-	-	-	-	2	4
-	-	-	-	-	-	-	-	-	-	-	-	1
5	-	1	3	1	12	1	-	1	-	2	14	16
18	8	2	23	11	97	12	30	5	4	51	148	219
1	2	1	8	5	37	6	11	1	2	20	57	96
2	5	1	8	5	50	4	-	-	1	5	55	56
-	-	-	-	-	-	-	-	-	-	-	-	2
-	-	-	-	-	1	-	1	-	-	1	2	6
1	-	-	1	2	4	-	-	-	-	-	4	8
7	1	2	8	3	30	2	-	1	-	3	33	40
-	-	-	1	-	1	-	-	-	-	-	1	1

AN = *Cx. annulirostris*, Q = *Cx. quinquefasciatus* and S = *Cx. sitiens*.

TABLE 13. Invertebrate fauna associated with mosquito larval habitats.

Taxa	Natural sites						
	Ground pool	Tree hole (small)	Tree hole (large)	Coconut	Coconut spathe	Leaf axil	Clam shell
Number of collections	8	16	4	35	1	3	4
(With associated invertebrates)	8	12	4	32	1	2	2
With associated invertebrates, non-Culicidae	1	11	1	18	0	0	0
Protozoa	-	-	-	-	-	-	-
Mollusca	1	-	-	2	-	-	-
Annelida	-	-	-	-	-	-	-
Arthropoda							
Diplopoda	-	-	-	-	-	-	-
Insecta							
Collembola	-	-	-	1	-	-	-
Hemiptera	-	-	-	-	-	-	-
Coleoptera	1	-	-	-	-	-	-
Diptera	8	12	4	32	1	2	2
(Diptera, excluding Culicidae)	-	11	1	17	-	-	-
Diptera subdivisions							
Psychodidae	-	2	-	6	-	-	-
Chironomidae	-	-	-	-	-	-	-
Ceratopogonidae	-	11	1	3	-	-	-
Culicidae	8	7	4	25	1	2	2
Cecidomyiidae	-	-	-	14	-	-	-
Cyclorrhapha (undetermined)	-	-	-	5	-	-	-

	Artificial sites											
	Large							Small				
Subtotal	Drum	Cistern	Tin	Tire	Miscellaneous large	Subtotal	Water seal toilet	Tin can	Bottle	Miscellaneous small	Subtotal	Total
71	35	26	2	23	11	97	12	30	5	4	51	219
61	32	17	2	19	9	79	8	16	3	2	29	169
31	1	3	0	6	2	12	2	8	1	0	11	54
-	-	-	-	1	1	-	-	-	-	-	-	1
3	-	-	-	-	-	-	-	2	-	-	2	5
-	-	-	-	-	-	-	-	1	-	-	1	1
-	-	-	-	-	-	-	-	1	-	-	1	1
1	-	-	-	-	-	-	1	5	-	-	6	7
-	1	3	-	-	-	4	-	-	-	-	-	4
1	-	1	-	-	-	1	-	-	-	-	-	2
61	32	14	2	19	9	76	7	15	3	2	27	164
29	-	-	-	5	2	7	1	3	1	-	5	41
8	-	-	-	3	1	4	-	1	-	-	1	13
-	-	-	-	1	-	1	1	1	-	-	2	3
15	-	-	-	-	1	1	-	-	-	-	-	16
49	32	14	2	17	9	74	7	12	2	2	23	146
14	-	-	-	-	-	-	-	1	1	-	2	16
5	-	-	-	1	-	1	-	2	-	-	2	8

(large tin cans also included *Cx. quinquefasciatus* and *aegypti*).

Only 3 non-arthropod phyla were collected: the Protozoa, Mollusca and Annelida. The Protozoa was represented by the ciliate ectocommensal, *Vorticella* (probably *microstoma*), which was found on *Cx. quinquefasciatus* in an old tire from Te'ekiu. Although *tongae tabu* was collected from the same tire, *Vorticella* was observed only on *Cx. quinquefasciatus*. Laird (1956) made 7 collections on Tongatapu in 1953 and found *Vorticella microstoma* Ehrenberg on *Cx. annulirostris* from a pond near Ola Ola, and on *vexans* from a brackish pond at Fanga Uta Lagoon. The Mollusca, all Gastropoda (snails), were found in 5 samples: a ground pool, 2 coconuts - drinking and split and 2 tin cans. Oligochaeta (phylum Annelida) were encountered with snails and *tongae tabu* in a tin can. The arthropod class Diplopoda (millipedes) was collected from a tin can with *tongae tabu* and cyclorrhaphous larvae. Other than Diptera, the Insecta included 3 orders. Collembola were represented in 7 samples - 5 from tin cans, a water seal toilet and a coconut; the Collembola were associated with *tongae tabu* in 3 tin cans, twice with Cecidomyiidae, a tin can and a coconut and as the only invertebrate in a water seal toilet and a tin can. Hemiptera included the families Notonectidae, Gerridae and Veliidae, all from large artificial containers. Notonectidae, which are voracious predators of mosquito larvae were collected in a large drum with *tongae tabu, Cx. quinquefasciatus* and *aegypti*, and a concrete cistern negative for mosquitoes but associated with the predatory Gerridae and Dytiscidae. The Geriidae and Veliidae were collected twice from concrete cisterns, both negative for mosquitoes and other noticeable invertebrates. Coleoptera (Dytiscidae) were recovered twice, in a ground pool in Te'ekiu with *Cx. annulirostris, vexans* and Gastropoda, and in the cistern above with Notonectidae and Gerridae.

Non-culicid Diptera associated with tongae tabu. Of the non-culicid associated invertebrates, the order Diptera was included in 75.9% of the samples and accounted for 24.3% of all samples positive for invertebrates including Culicidae. Psychodidae, *T. vitiensis*, were found in 13 samples: 6 coconuts - associates, *tongae tabu* (4), Cecidomyiidae (5), Ceratopogonidae (2) and cyclorrhaphous Diptera (2); 2 small tree holes - *tongae tabu* (2), *Cx. quinquefasciatus* (1), Ceratopogonidae (2); 3 tires - alone twice, and with *Cx. quinquefasciatus* once; a washtub with *Cx. annulirostris* and a tin with *Chironomus* sp. Chironomidae, all *Chironomus* sp., were taken only in artificial containers (3): a water seal toilet with *tongae tabu* and *aegypti*, a tire with *tongae tabu, Cx. quinquefasciatus* and *Cx. sitiens*, and a tin can. Ceratopogonidae represented 29.6% of the samples positive for non-culicid invertebrates, of which 48.4% were from natural sites. All were *D. hitchcocki* and, as usual, it dominated the tree hole habitat. Twelve of 20 (60%) were positive for *D. hitchcocki* while only 11 (55%) were positive for *tongae tabu* (68.8% of the small tree holes to 43.8% for *tongae tabu*). It was in association with *tongae tabu* in 7 samples and with *Cx. quinquefasciatus* in 2. Psychodidae were also found twice with *tongae tabu* and once with *Cx. quinquefasciatus*. It was the only invertebrate found in 5 tree holes, and in 2 of those, *D. hitchcocki* was so abundant that it may have influenced the absence of *tongae tabu*. Coconuts provided 3 collections: once on its own, once with *tongae tabu*, Psychodidae and Cecidomyiidae and finally with Psychodidae, Cecidomyiidae and cyclorrhaphous larvae. It was also taken in an artificial container (a bucket) with *tongae tabu*. Cecidomyiidae (*Resseliella* sp.) were equal to Ceratopogonidae with 16 positive samples and it was the dominant non-culicid invertebrate in coconut shells (77.8% positive). It was associated with *tongae tabu* (8), cyclorrhaphous Diptera (4), Psychodidae (5), Ceratopogonidae (2), Collembola (1) and Gastropoda (1). *Resseliella* were

also taken from 2 artificial containers (quite similar to coconuts) both negative for mosquitoes, a tin can with Collembola and a discarded beer bottle. Undetermined cyclorrhaphous larvae were collected on 8 occasions: 5 coconuts, with *tongae tabu* (3), Cecidomyiidae (4), Psychodidae (2), Ceratopogonidae (1) and alone (2); and 3 artificial containers: 2 tin cans one with *tongae tabu* and Diplopoda, the other with Gastropoda and a tire with *Cx. quinquefasciatus*.

Biting activity. Aedes tongae tabu is a diurnal biter, common throughout the Tongatapu group, being more abundant on small uninhabited islands (especially where numerous crab holes are in evidence) and in the bush, than within villages, although it is among the dominant peridomestic species. It was collected from sea level to over 150 m elevation. Ramalingam (1965; unpublished Ph. D. thesis, l. c.) describes a biting activity pattern where the peak activity is between 1000-1200 h, with a smaller late afternoon peak. He found none biting before sunrise or after sunset and concluded that it was strictly diurnal and a crepuscular biter. Although Ramalingam did not find *tongae tabu* inside houses (1968; 1976; unpublished Ph. D. thesis, l. c.), we found that it was a distant 2nd to *Cx. quinquefasciatus* in abundance and the same as *oceanicus* for species captured inside houses, based on 6 village surveys (4 in Te'ekiu, 2 in Longoteme) directed specifically at mosquitoes captured inside houses in the daytime. A total of 256 houses were surveyed, 155 (60.5%) of which were positive for indoor mosquitoes. *Culex quinquefasciatus* was recovered from 102 (39.8% of all houses and 64.8% positive), followed by *tongae tabu* and *oceanicus* with 19 positive (12.3%), *aegypti* with 18 (11.6%) and *vexans* 12 (7.7%). While *Cx. quinquefasciatus* were collected in all abdominal stages from freshly fed to fully gravid, *tongae tabu* were either non-fed or freshly fed which meant that they were primarily entering the house to bite and that they departed soon after feeding, giving a point prevalence rate, rather than the accumulative rate (3 or 4 days) of *Cx. quinquefasciatus*, *aegypti* and *vexans*. Consequently, the importance of *tongae tabu* as an indoor-biting mosquito is grossly underestimated. During our studies, 25 timed 10 minute biting-landing collections were made at the same location on Tongatapu (Popu Hill) in the bush about 3.2 km east of Nuku'alofa. During the 250 minutes, 1,119 *tongae tabu* were collected (plus 34 male *tongae tabu* and 5 female *vexans*), averaging 44.8/10 min period. The 10 minute periods were between 0720-1300 h in 6 groups (3, 7, 4, 4, 3, 4; 15, 16, 17, 18, 19, and 20 April 1974 between 1035-1112, 0720-0855, 1140-1230, 0900-0945, 0853-0930 and 1205-1300 h respectively). The biting activity pattern from 0720-1300 h remained relatively constant. Although there were 25 to 88 *tongae tabu* females per 10 minute period, the mean number collected during any particular batch of collections was never greater than 5 mosquitoes from the overall mean of 44.8/10 min period. The mode of 25 collections was 44 and the frequency distribution showed that the greatest number of collections, 8 (32%) were in the 40-49 mosquito category with the mean of the means 44.4 (less than 0.5 from the overall mean). This series of grouped collections clearly demonstrates the phenomenon observed during our studies in other members of the *scutellaris* group, that is, they tend to attack bait in waves and not on a regular random schedule which partly accounts for the variation in numbers among closely timed collections. For example, one series (0720-0855 h) shows a build-up over time from 25 to 88 (25, 27, 35, 48, 61, 88) with a drop in the last collection of the series to 43. Another series (0900-0945 h) showed a constant decline, i.e. 63, 49, 34 and finally 27. All other collection series showed an up-down-up or up-down-up-down pattern indicating roughly the number of waves

during each 10 minute period and also something of the intensity of each wave. The interpretation given to the first example would be, that as the bait remains in the area, more and more mosquitoes are attracted to the bait and are drawn in from greater distances, with the last collection of the series suggesting that the available mosquitoes ready for a blood meal in the area have been depleted. The 2nd example would be explained on the basis that the available mosquitoes in the area were being gradually depleted. When the overall picture is examined, these interpretations may not be valid since the average number of mosquitoes biting per series remained constant. The largest number of mosquitoes captured during any 10 minute period was 88 at 0832-0841 h, after 50 minutes of collecting, suggesting an early morning peak similar to that observed for *kesseli* on Niuatoputapu. In a crab hole area on Pangaimotu (September 1973), 2 sequential collections provided 49 and 14 female biting-landing *tongae tabu* (1230-1239 and 1243-1252 h). The highest series in a village was 12 and 14 (0905-0914 and 0920-0929 h), in back of a house near the peripheral bush in Te'ekiu prior to the village survey (9 August 1974). On Eua the highest series obtained was 14, 22, 8 (1000-1009, 1015-1024 and 1030-1039 h 21 December 1973). Biting-landing surveys carried out in Te'ekiu village on Tongatapu with *tongae tabu* in August and December 1974 and showed much lower activity than comparable surveys with *cooki* and *kesseli*. During August, 77 premises were surveyed, of which only 15 (19.5%) were positive for mosquitoes, of which 14 were *tongae tabu* (18.2%) for a total of 5 males and 26 females in 770 minutes of collecting, i.e. 0.03 females/min. In December, the biting-landing collections were terminated after 18 houses (180 minutes of collecting) as only one female *tongae tabu* was recovered, i.e. 0.006/min. During the August survey, one *aegypti* and one *oceanicus* were also taken as biting-landing females. Because of the low biting activity observed during the first 3 days of the August survey (after 61 houses), a spot check was made at Popu Hill at midday (1205-1214 and 1218-1227 h on 22 August) to ascertain if the overall mosquito biting activity was reduced on Tongatapu. The results were similar to those found in April 1973, i.e. 53 and 28 *tongae tabu* respectively for the 2 sequential collections. It is obvious that the peridomestic biting activity of *tongae tabu* in Te'eikiu village does not compare with the biting frequencies encountered in similar surveys among the closely related species further north. Although the numbers dissected were small, there was a large proportion of *tongae tabu* which returned for a blood meal soon after oviposition in the bush (Popu Hill) and in the village (Te'ekiu). Of the parous females, 28.6% (12/42) had dilated follicular tubes (sacs) which returned to normal within 24 hours of oviposition. Dilated follicular tubes were found in 22.6% of the 1-parous females (7/31) and almost half (45.5%) of those in the older age groups (5/11). Retained eggs were observed in 3 females (3/31 parous). Nullipars accounted for over half (53.8%) of the females derived from the village biting-landing survey (14/26) while only 26.8% (11/41) of the bush-caught and inside of house-caught *tongae tabu* were nulliparous. The sac rates for the village biting-landing females (5/12, 41.7%) also differed from the bush, indoor females (7/30, 23.3%).

Fecundity. Fifty *tongae tabu* were isolated for individual oviposition and deposited 2,784 eggs. The mean number of eggs was 55.7 per female with a median of 49 and modes of 40-49 (10), 30-39 (9) and 70-79 (9). The egg batches were from 2 sources, 19 from Pangaimotu, an island near Nuku'alofa from females collected on 26 September 1973 and 31 females from Eua, the type-locality of *tongae tabu* in December 1973. The Pangaimotu females provided a mean of 54.0 eggs per clutch with a median of 50 and a mode of 40-49;

while the Eua females had a bimodal distribution with 30-39 (8) and 70-79 (7), a mean of 56.7 and a median of 48. Among the Eua *tongae tabu* collected, some females were at the time recorded as small or large. Of those that produced normal egg batches and did not die during oviposition, there were 6 small with a mean clutch of 31.5 and a range of 22-38*, and 7 large which averaged 84.7 per clutch and a range of 4-129**. The presence of small and large individuals (41.9% of the sample, 13/31) helps to account for the bimodal distribution.

Gonotrophic cycle. Precise time measurements were made on females collected and fed on Eua, then transported to Tongatapu for observation. Feedings were made on 20 and 21 December 1973 and observations were made on commencement of oviposition on 23 December from 0200 h (25 observations), 24 December (39 observations) and 25 December (13 observations). The observations were at 30 minute intervals until 2300 h on 23 December, then hourly until 0500 h, 24 December; then twice hourly until midnight followed by 0100 h and 0300 h on 25 December when the last ovipositions were observed for those females fed on Eua. The first female oviposited between 1400-1430 h on 23 December which was 76.5 h from its feeding. The commencement of oviposition for 28 females studied ranged from 67.5-85.5 h with a mean of 76.7 h and a median of 76 h. By 80 h, 71.4% commenced oviposition. During the last 5 hours of day 3, i.e. 67-71 h, 28.6% oviposited, while the remainder had all oviposited during the first 13 hours of day 4. As with fecundity, there seems to be a difference also in the length of the gonotrophic cycle between the noticably small and large *tongae tabu* captured on Eua, with a longer average gonotrophic cycle observed among the small (79.8 h, 478.5/6) as compared to the large (71.6 h, 501/7).

Autogeny. Aedes tongae tabu, as with other members of the *scutellaris* group in the Tonga area was shown to be autogenous among adults derived from eggs laid by females collected and fed on Eua Island, the type-locality (Hoyer and Rozeboom 1977).

Mermithid parasitism on tongae tabu. A biting-landing female *tongae tabu* collected in Te'ekiu village on 22 August 1974 was found infected with 6 mermithids of various sizes, all in the abdomen. The mosquito was nulliparous with ovaries in a retarded condition similar to that observed in teneral females, and not in Christophers' stage II as usually seen in biting-landing females of the *scutellaris* group. This is the first record of parasitism by the nematode (Mermithidae) in *tongae tabu* and the 2nd record in Tonga mosquitoes (see *kesseli*).

MEDICAL IMPORTANCE. *Aedes tongae tabu* is the major vector of filariasis in the Tongatapu group, where during the present studies, it was found naturally infected with *W. bancrofti,* and for the first time with *D. immitis.* It has been experimentally infected with dengue-2 and is a suspect vector of dengue-1.

Filariasis. Aedes tongae tabu was shown to be a vector of *W. bancrofti* by Ramalingam in 1963 (Ramalingam and Belkin 1964; Ramalingam 1968 and unpublished Ph.D. thesis, l.c.), based on natural infections in which 6.1% (16) of 264 wild caught females were positive for *W. bancrofti* and one (0.38%) was found positive for stage III larvae. Ramalingam also experimentally infected 12 laboratory reared females, 8 of which were positive for larvae, and of those, 6 had stage III larvae. In our studies, only 67 *tongae tabu* were

*Small - 22, 26, 28, 37, 38, 38 eggs/female.

**Large - 45, 72, 72, 74, 74, 127, 129 eggs/female.

dissected as a result of village surveys in Te'ekiu (26 from biting-landing surveys, 11 from house-resting surveys) and Popu Hill (30 biting-landing), however, 2 females were found naturally infected with *W. bancrofti* (a female from Popu Hill with a stage I larva and another from a biting-landing survey in Te'ekiu with 9 stage I larvae; both females were 1-parous). We made 2 parasitological surveys in Te'ekiu, 1972 (Desowitz and Hitchcock 1974) and 1973 (Desowitz et al. 1976). The 1972 survey was the first village survey made in the Tongatapu group. The 1973 microfilaria rate for all 297 villagers was 37.4% by the membrane filter concentration technique, and was estimated to be about 20% (19.9%) by the 60 cmm blood films. The rate for the 114 villagers in age groups 20 and older was 58.8% and 22.8% for the 2 techniques. Although the rates were lower than Ha'aipai, and especially Niuatoputapu, they still showed a high endemicity which would indicate a relatively high transmission rate. Biting-landing collections were made in August and December 1974 with a total of 95, 10 minute human bait collections. Each collection was outside of a house, however, only 16.8% of the collections were positive for biting-landing mosquitoes, 15 for *tongae tabu* (5♂, 27♀) including one house with a biting-landing *oceanicus* and a single *aegypti* at an additional premises. The overall biting-landing *tongae tabu* rate for this village was only 0.028/min. The December survey provided only one *tongae tabu* in 180 minutes of collecting. In biting activity above, it was noted that a spot check in Popu Hill could confirm whether the mosquito density was much lower than usual, but there was little difference between the April 1973 collections and the August 1974 collections. Surprisingly, the 0-4 age group in Te'ekiu showed a microfilaria rate of 56.4% (22/39) which would indicate no radical reduction in transmission in recent years (in general, the appearance of the village changed little since it was first surveyed in 1972). House-resting and larval surveys of the village were also made in August and December 1974 as well as April 1975. The larval and house-resting surveys confirmed the paucity of mosquitoes. The Breteau indices for total immature *tongae tabu*, *aegypti* and *Cx. quinquefasciatus* were: August 41.3 (33 positive sites found on 80 premises), 28.8 (23/80), 3.8 (3/80) and 10 (8/80); December 5.7 (2/35), no *tongae tabu* or *aegypti* were found during the survey of 35 premises and the 2 positive sites found were producing *Cx. quinquefasciatus*, providing a total of 8 larvae and 2 pupae; April 46.4 (26/56), 30.4 (17/56), 0.0 (0/56) and 16.1 (9/56). The number of immature *tongae tabu* collected were: August 887 (782 larvae, 105 pupae) from 23 collections; December none; April 482 (422 larvae, 60 pupae). The 3 positive collections for *oceanicus* provided 23 larvae and 2 pupae. House-resting surveys in Te'ekiu in August showed resting mosquitoes in 57.4% of the 61 houses surveyed, 10 of the positive houses harbored *tongae tabu* (28.6%), while *oceanicus* was found resting in 11 (31.4%), *aegypti* in 2 (5.7%) and *Cx. quinquefasciatus* in 22 (62.9%) of the houses. To explain the relative high endemicity of *W. bancrofti*, especially considering the high microfilaria rate observed in the 0-4 age group in the village, it appears that 2 vectors must be included within the village, *tongae tabu* and *oceanicus*. It appears that *oceanicus* may be the major vector in this village since the *tongae tabu* population densities appear to be too low to support, on their own, the hyperendemic situation observed, as well as the transmission rate necessary to produce microfilaremia in over 50% of the 0-4 age group. Bush transmission by *tongae tabu* could account for the high endemicity of *W. bancrofti* found in the village among older age groups, but would not provide the prevalence rate found in the very young. Consequently, *oceanicus* which was shown to be an efficient vector in the north (Hitchcock 1971), may be the major vector of *W. bancrofti* in

in Te'ekiu village on Tongatapu. However, for most villages and in the bush on Tongatapu, *tongae tabu* is probably still the major vector of *W. bancrofti*. *Aedes tongae tabu* was found naturally infected with a stage III larva of *D. immitis* in a 3-parous female found inside a house in Te'ekiu on 29 August 1974. It is the first record of *D. immitis* in *tongae tabu*.

Dengue. An outbreak of dengue-2 virus occurred on Tongatapu in 1974. It was relatively mild with low viremia levels and few hemorrhagic manifestations, however, in 1975 there was an explosive outbreak of dengue-1 which was relatively severe, providing numerous cases with hemorrhagic manifestations (Gubler et al. 1978). We undertook a series of studies directly related to the dengue outbreaks, including the infecting of *tongae tabu* with dengue-2 virus from a patient with a subsequently serologically confirmed case of dengue-2. Additional experimental artificial feeding of *tongae tabu* with dengue-2 virus by Dr. Gubler in Hawaii, established salivary gland infections of the virus. House-resting and larval surveys were made in 2 entire villages, Lonoteme (house-resting April and June 1973, larval June 1973) and Te'ekiu (house-resting and larval surveys August, December 1974 and April 1975) and additional collections of both types were made on premises of suspected dengue patients. The 6 villages surveyed included 256 houses of which 155 (60.5%) were positive for indoor mosquitoes. In order of abundance they were: *Cx. quinquefasciatus* 102 (65.8% of those positive), *tongae tabu* 19 (12.3%), *oceanicus* 19 (12.3%); *aegypti* 18 (11.6%) and *vexans* 12 (7.7%). The comparative rates for the 46 houses surveyed which had suspected dengue patients were different, i.e. 43 positive (93.5%): *Cx. quinquefasciatus* 31 (72.1%), *aegypti* 26 (60.5%), *vexans* 17 (39.5%), *tongae tabu* 3 (7.0%) and *oceanicus* 2 (4.7%). The mean number of females by species per positive house in the village survey followed by dengue patients' houses were: *Cx. quinquefasciatus* 1.39 (216/155), 3.67 (158/43); *tongae tabu* 0.14 (21), 0.14 (6); *aegypti* 0.21 (33), 1.9 (82); *oceanicus* 0.14 (21), 0.047 (2) and *vexans* 0.09 (12), 0.53 (23). It can be seen that there was a 9-fold difference in the mean number of *aegypti* per infected house in the village surveys as compared to the dengue patients' houses, i.e. 0.21 to 1.90, while *tongae tabu* showed identical percentages of 0.14 per positive house. The average number of mosquitoes per positive house was: 20 (305/155) and 6.3 (271/43), a 3.2-fold difference. Besides the great differences observed in both the rate and density of *aegypti* in houses with suspect dengue cases, and those from systematic village surveys, it also showed that houses of dengue patients generally had larger numbers of mosquitoes. Also, whereas in village larval surveys many premises have no immature habitats, virtually all the premises surveyed where suspected dengue patients lived, had immature mosquito habitats. It is unfortunate that *tongae tabu* indoor samples are point prevalence counts and not comparable to house-resting mosquitoes such as *Cx. quinquefasciatus* and *aegypti*, but the indoor surveys do show the uniform, widespread nature of the *scutellaris* group in general and point out a greater activity indoors than hitherto suspected.

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LITERATURE CITED

BELKIN, J. N.
1962. The mosquitoes of the South Pacific (Diptera, Culicidae). Univ. Calif. Press, Berkeley and Los Angeles. 2 vol., 608 and 412 p.

DESOWITZ, R. S., S. J. BERMAN and T. PULOKA
1976. Hyperendemic subperiodic Bancroftian filariasis: a search for clinical and immunological correlates of microfilaremia. Bull. W. H. O. 54: 565-71.

DESOWITZ, R. S. and J. C. HITCHCOCK
1974. Hyperendemic Bancroftian filariasis in the Kingdom of Tonga: the application of the membrane filter concentration technique to an age-stratified blood survey. Am. J. Trop. Med. Hyg. 23: 877-9.

EDWARDS, F. W.
1926. Mosquito notes.-VI. Bull. Entomol. Res. 17: 101-31.

GUBLER, D. J., D. REED, L. ROSEN and J. C. HITCHCOCK
1978. Epidemiologic, clinical, and virologic observations on dengue in the Kingdom of Tonga. Am. J. Trop. Med. Hyg. 27: 581-9.

HITCHCOCK, J. C.
1969. UCLA mosquito studies in Tonga - 1968. Proc. N. J. Mosq. Exterm. Assoc. 56: 116-23.

1970. Evaluation of filariasis mosquito surveys based on the physiological age of the vector. J. Parasitol. 56(4) Sect. II, Pt. 1: 129.

1971. Transmission of sub-periodic filariasis in Tonga by *Aedes oceanicus* Belkin. Trans. R. Soc. Trop. Med. Hyg. 65: 408-9.

HITCHCOCK, J. C. and L. E. ROZEBOOM
1973. Cross-breeding of *Aedes (S.) polynesiensis* Marks with an autogenous species of the *A. scutellaris* group. Bull. W. H. O. 49: 367-70.

HOYER, L. C. and L. E. ROZEBOOM
1976. Inheritance of autogeny in the *Aedes scutellaris* subgroup of mosquitoes. J. Med. Entomol. 13: 193-7.

1977. Genetic relationships between several autogenous and anautogenous populations of the *Aedes (Stg.) scutellaris* group of mosquitoes. J. Med. Entomol. 13: 463-8.

HUANG, Y.-M.
1972. A redescription of the holotype male of *Aedes (Stegomyia) tongae* Edwards with a note on two topotypic females (Diptera: Culicidae). Proc. Entomol. Soc. Wash. 74: 338-42.

1975. A redescription of *Aedes (Stegomyia) pseudoscutellaris* (Theobald) with a note on the taxonomic status of *Aedes (Stegomyia) polynesiensis* Marks (Diptera: Culicidae). Mosq. Syst. 7: 87-101.

1977a. The mosquitoes of Polynesia with a pictorial key to some species associated with filariasis and/or dengue fever. Mosq. Syst. 9: 289-322.

1977b. Medical entomology studies. VII. The subgenus *Stegomyia* of *Aedes* in Southeast Asia. II. - The *edwardsi* group of species. III. - The *w-albus* group of species. (Diptera: Culicidae). Contr. Am. Entomol. Inst. (Ann Arbor). 14(1): 1-111.

LAIRD, M.
1956. Studies of mosquitoes and freshwater ecology in the South Pacific. Bull. R. Soc. N. Z. 6: 1-213.

RAMALINGAM, S.
1968. The epidemiology of filarial transmission in Samoa and Tonga. Ann. Trop. Med. Parasitol. 62: 305-24.

1976. An annotated checklist and keys to the mosquitoes of Samoa and Tonga. Mosq. Syst. 8: 298-318.

RAMALINGAM, S. and J. N. BELKIN
1964. Vectors of sub-periodic Bancroftian filariasis in the Samoa-Tonga area. Nature 201: 105-6.

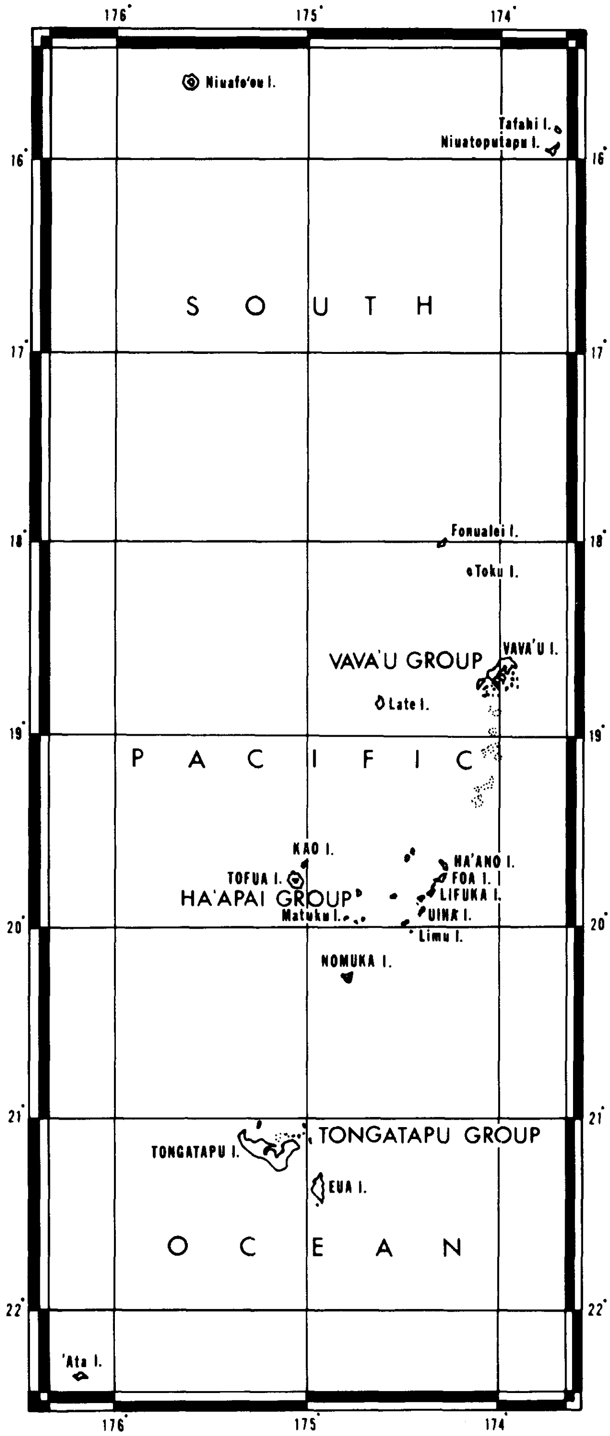
1965. Mosquito studies (Diptera, Culicidae) III. Two new *Aedes* from Tonga and Samoa. Contrib. Am. Entomol. Inst. (Ann Arbor) 1(4): 1-10.

WIRTH, W. W.
1976. A new species and new records of *Dasyhelea* from the Tonga islands and Samoa (Diptera: Ceratopogonidae). Proc. Hawaii. Entomol. Soc. 22: 381-4.

YUNCKER, T. G.
1959. Plants of Tonga. Bernice P. Bishop Mus. Bull. 220: 1-283.

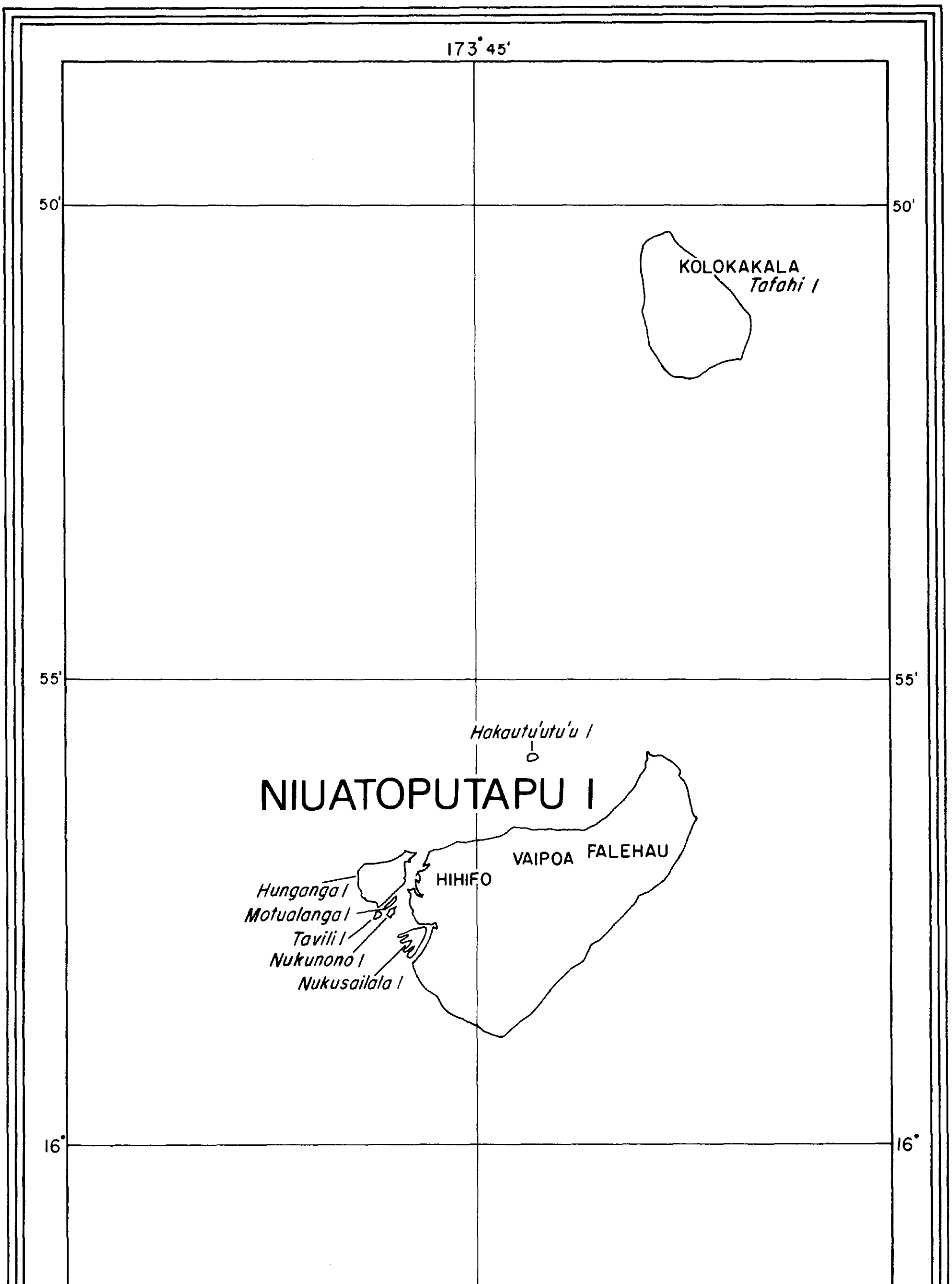
LIST OF MAPS

MAP I



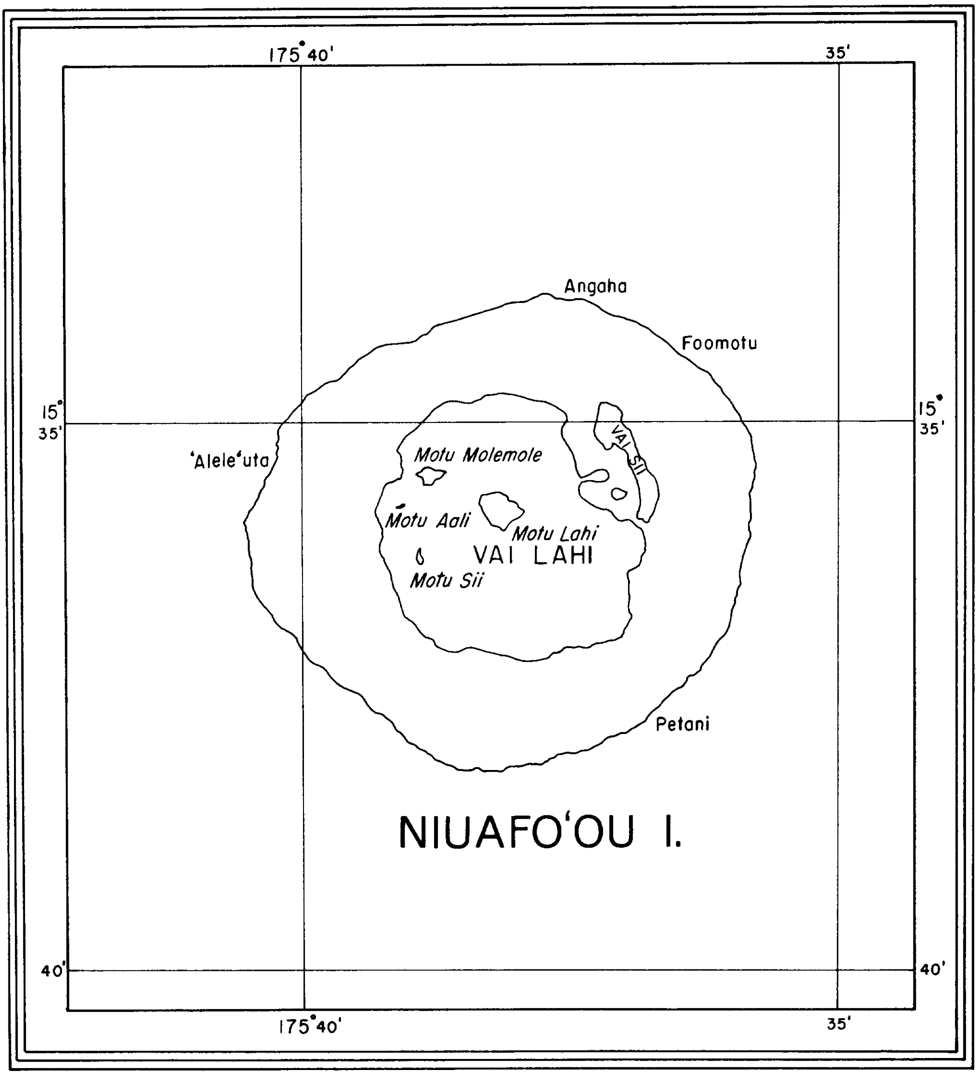
KINGDOM OF TONGA

MAP II



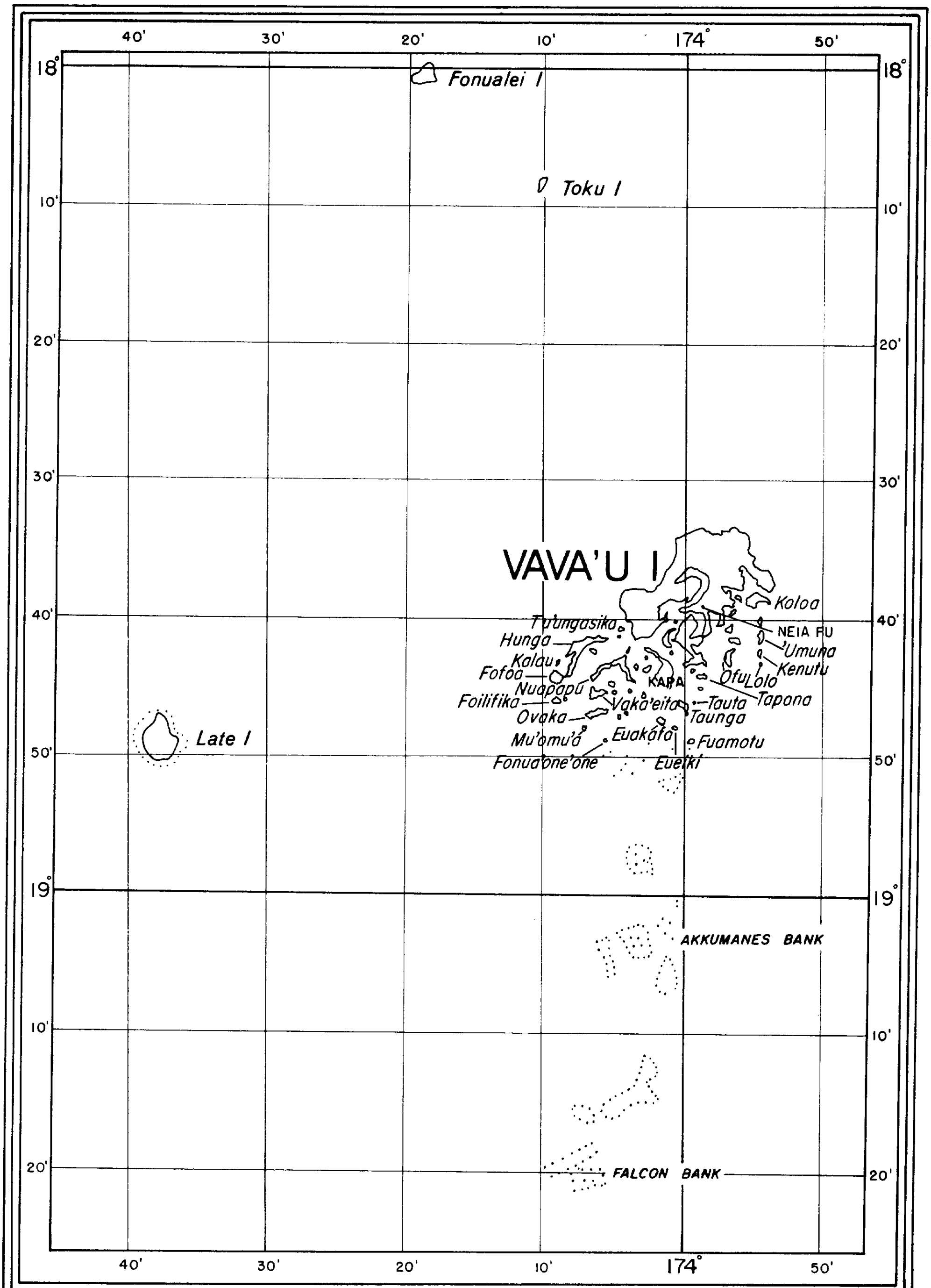
NIUATOPUTAPU GROUP

MAP III



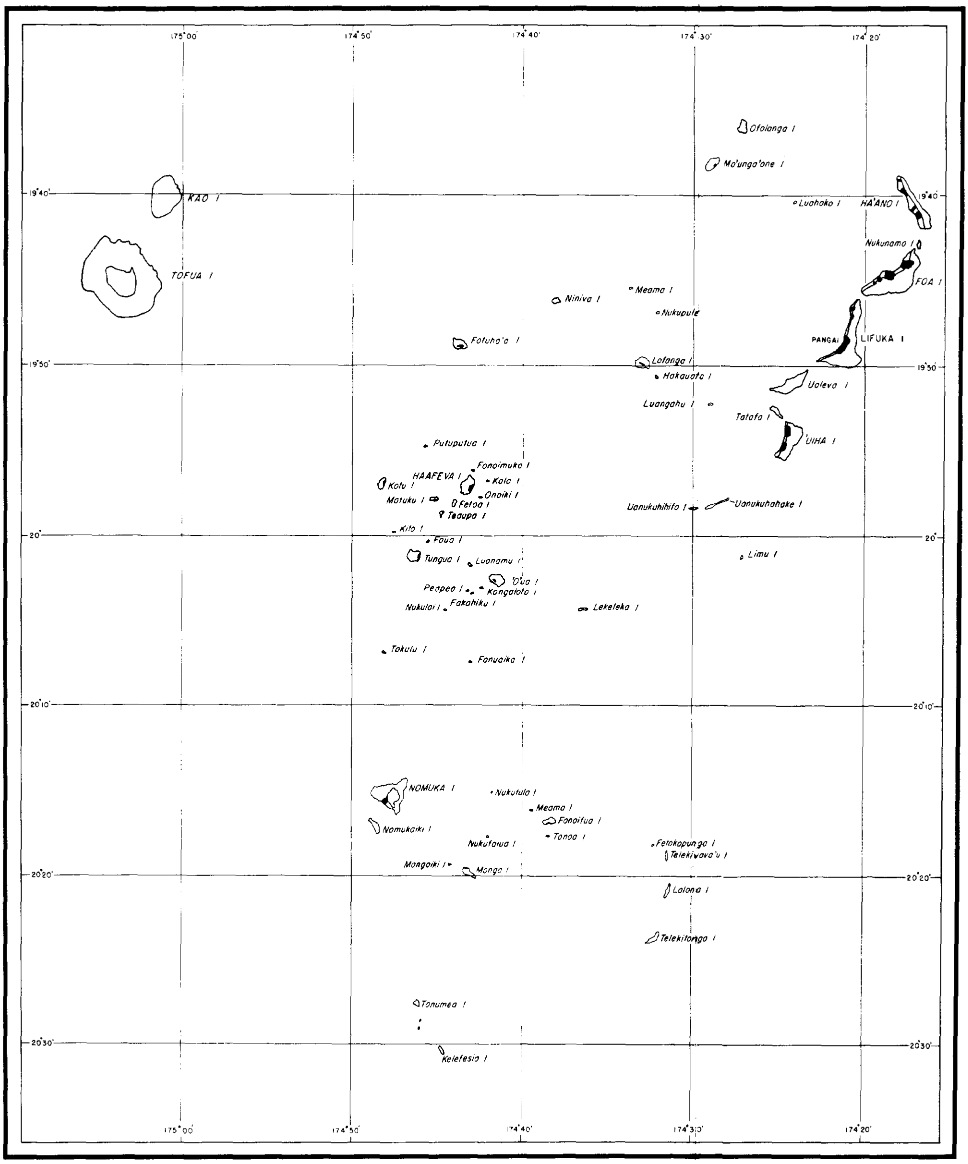
NIUAFO'OU ISLAND

MAP IV



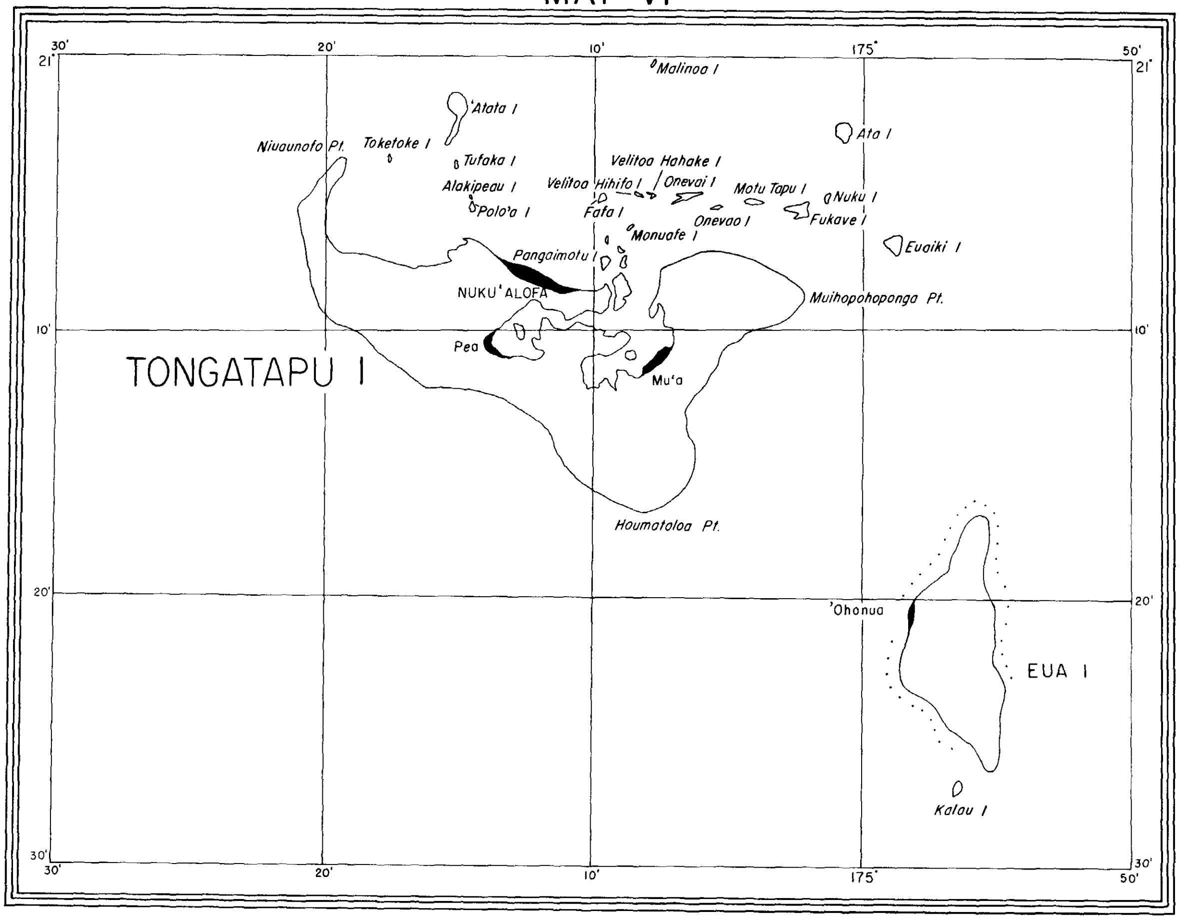
VAVA' U GROUP

MAP V



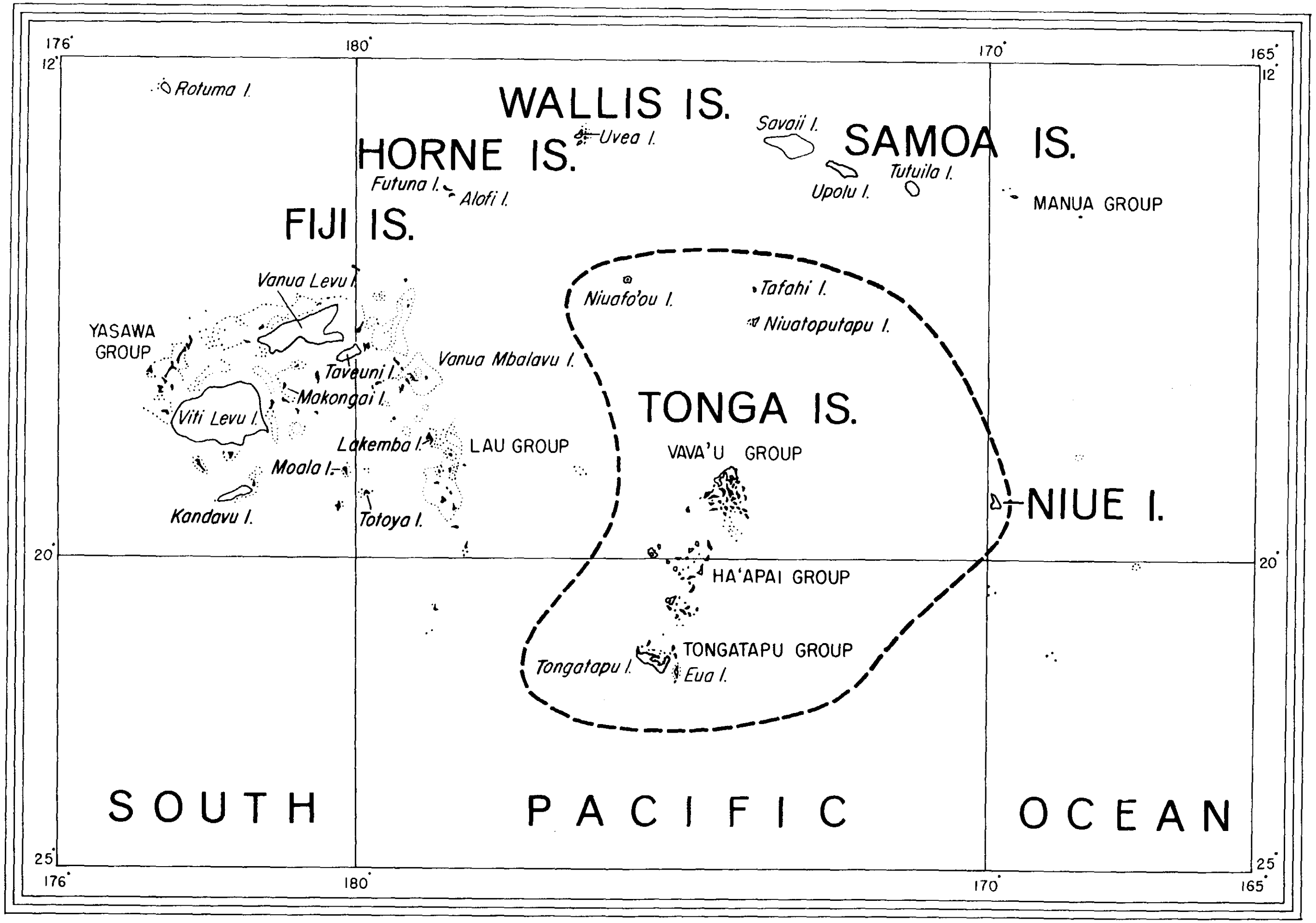
HA'APAI GROUP

MAP VI



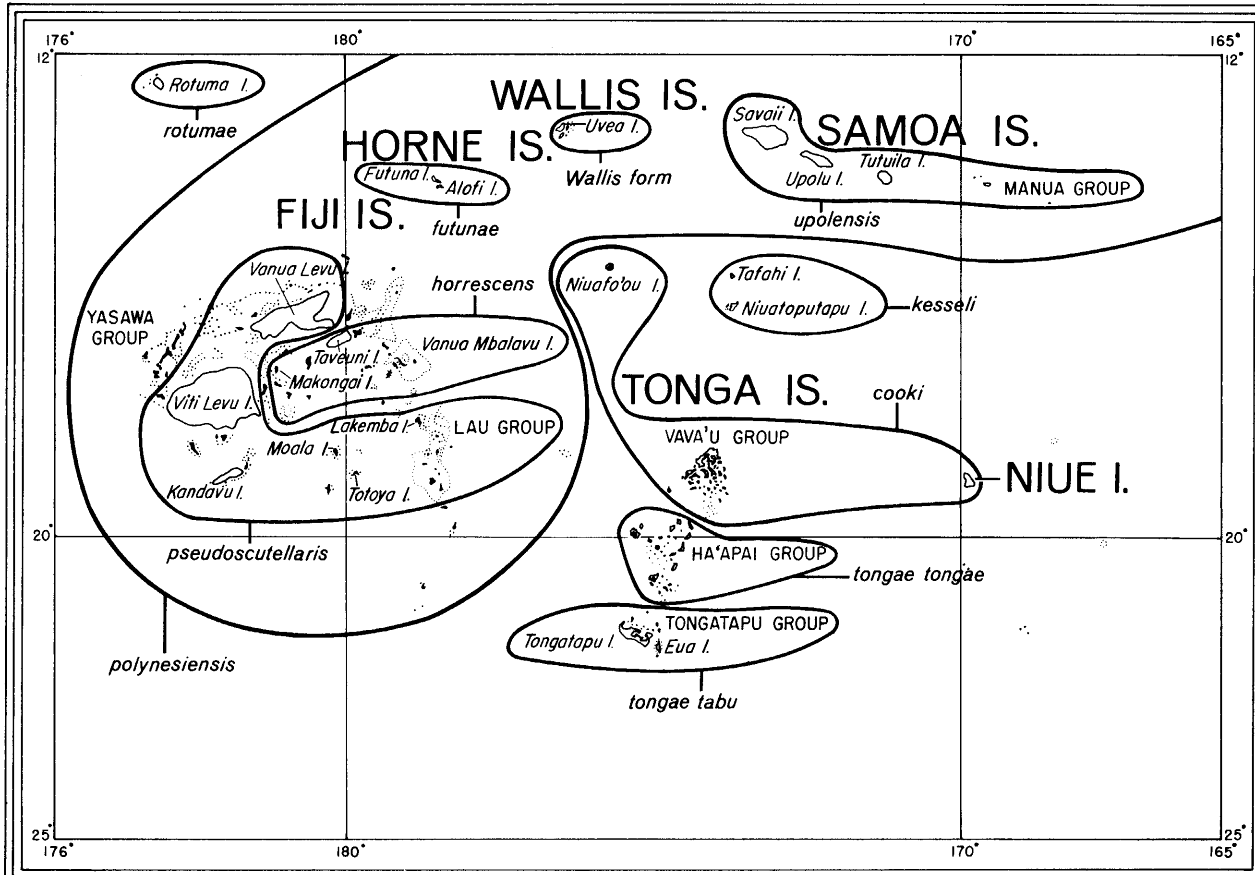
TONGATAPU GROUP

MAP VII



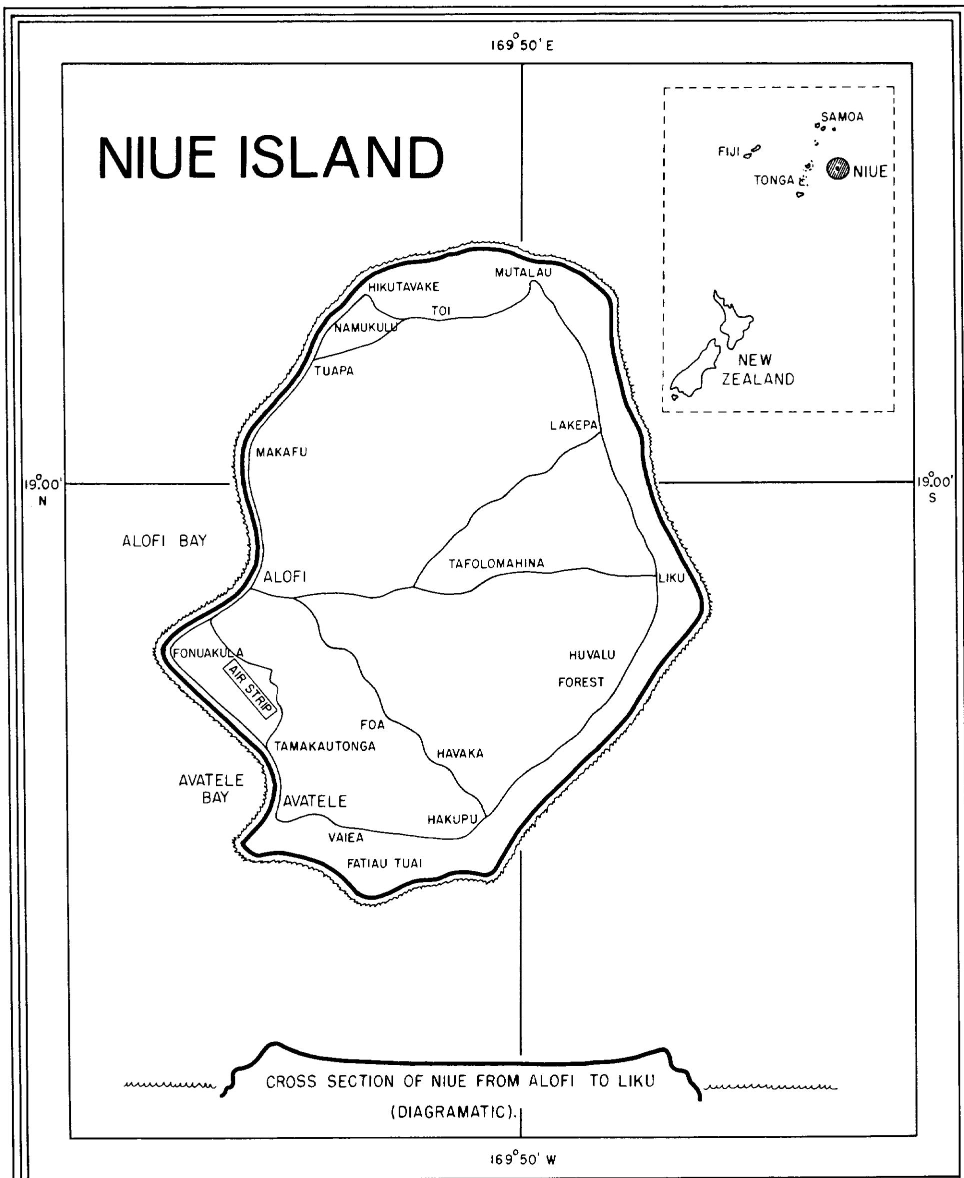
---- THE AEDES SCUTELLARIS GROUP OF TONGA

MAP VIII



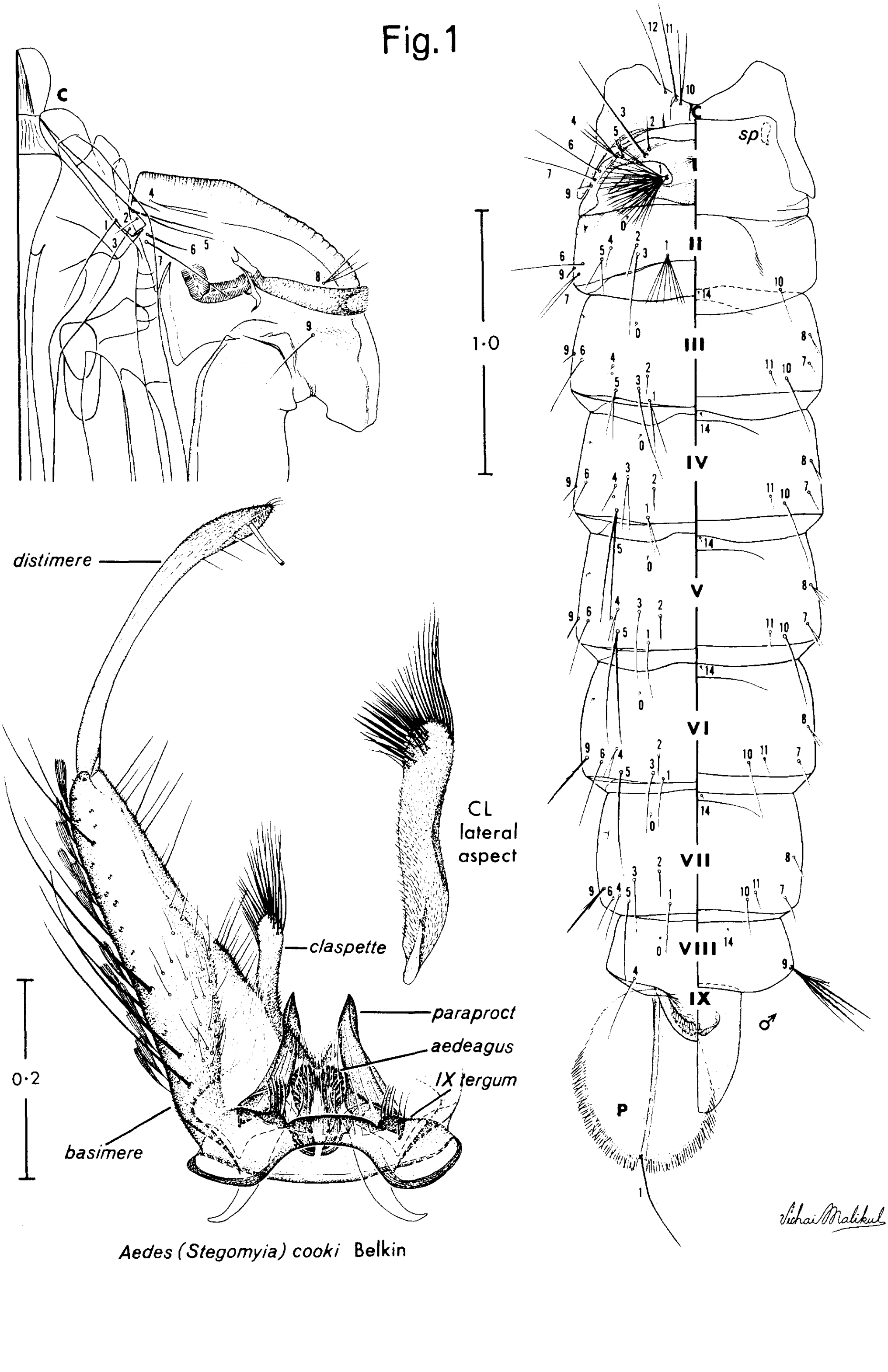
FIJI — TONGA — SAMOA

MAP IX

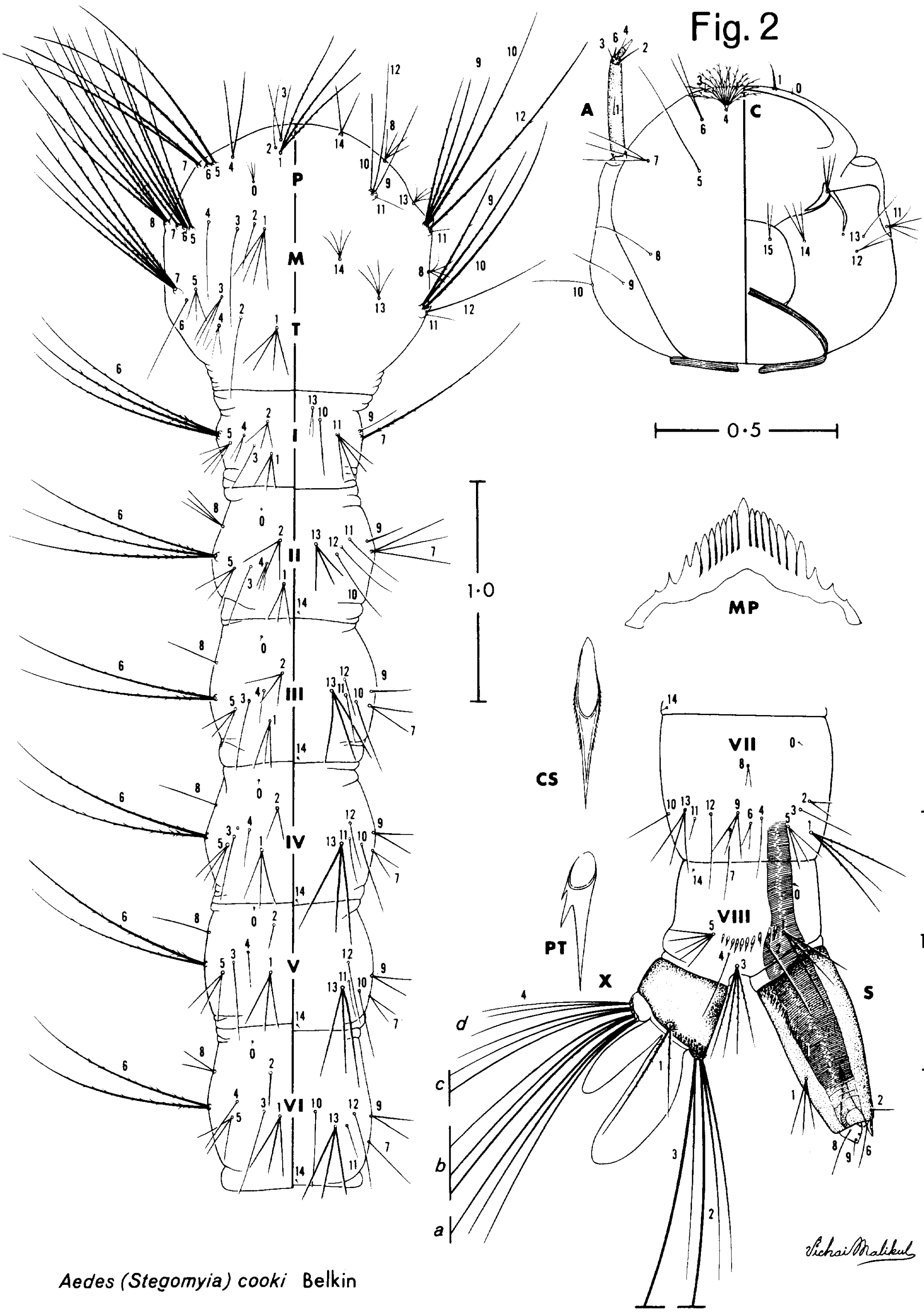

169°50' E
NIUE ISLAND
SAMOA
FIJI
TONGA
NIUE
NEW
ZEALAND
MUTALAU
HIKUTAVAKE
TOI
NAMUKULU
TUAPA
LAKEPA
MAKAFU
19°00' N
19°00' S
ALOFI BAY
ALOFI
TAFOLOMAHINA
LIKU
FONUAKULA
AIR STRIP
HUVALU
FOREST
FOA
TAMAKAUTONGA
HAVAKA
AVATELE
BAY
AVATELE
HAKUPU
VAIEA
FATIAU TUAI
CROSS SECTION OF NIUE FROM ALOFI TO LIKU
(DIAGRAMATIC).
169°50' W

LIST OF FIGURES

Fig. 1

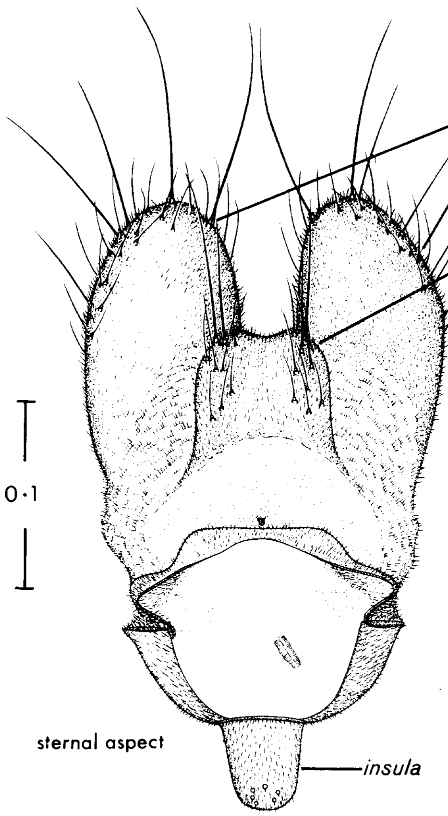


Aedes (Stegomyia) cooki Belkin

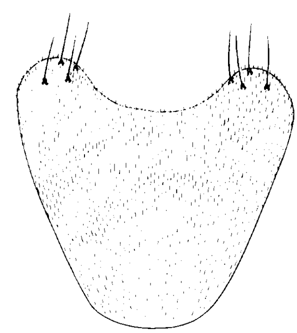


Aedes (Stegomyia) cooki Belkin

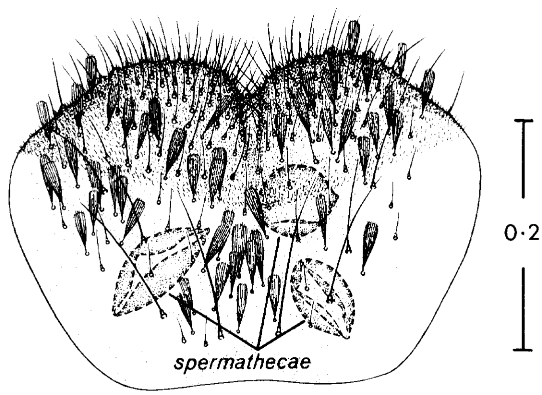
Fig. 3 ♀ terminalia



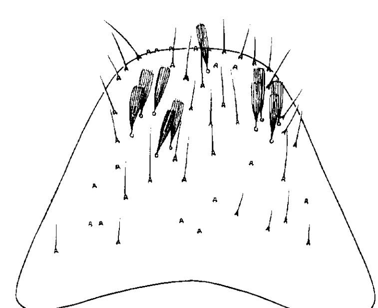
sternal aspect


IX tergum
dorsal aspect

0·1



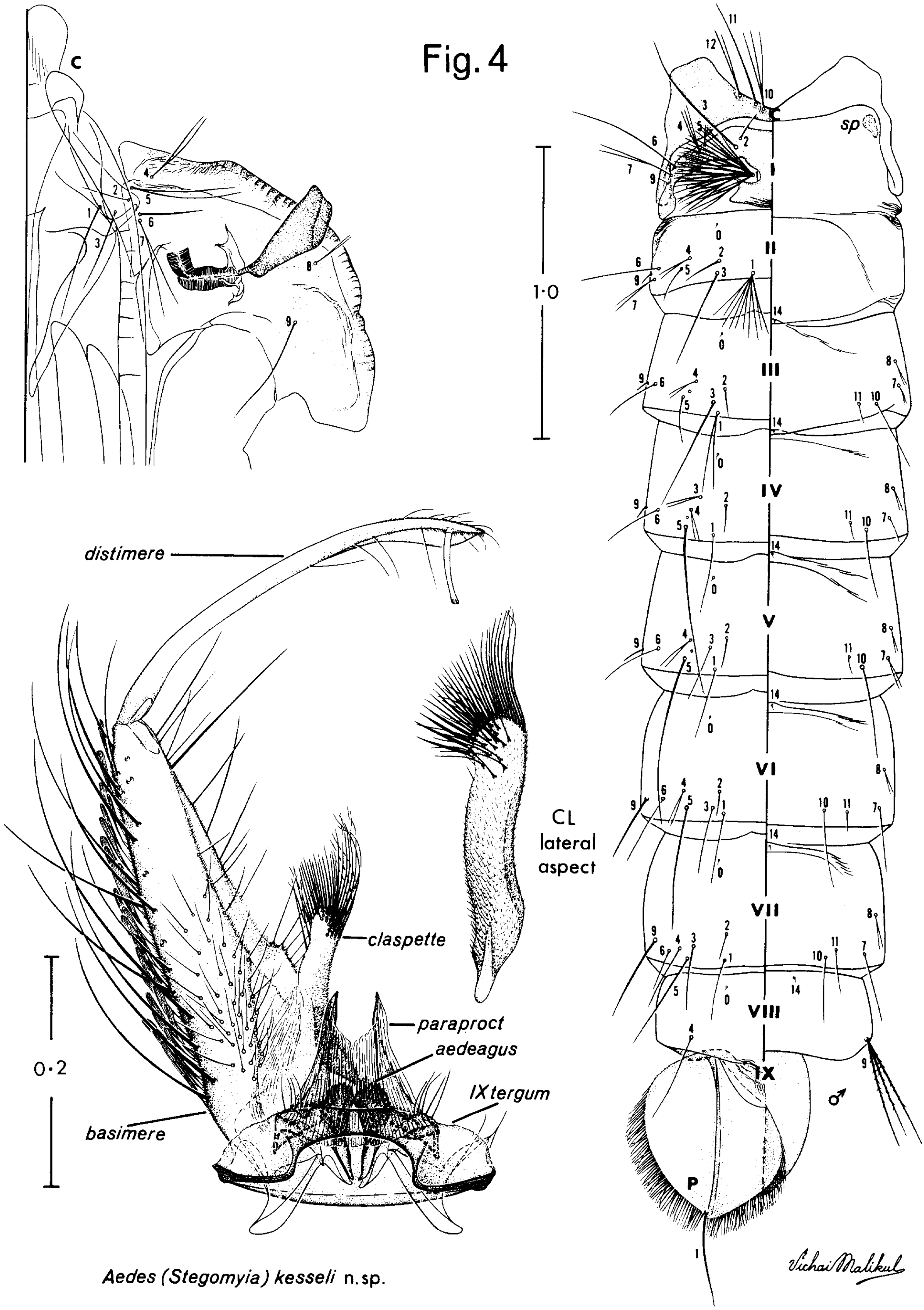
VIII sternum
dorsal aspect


VIII tergum
dorsal aspect

Vichai Malikul

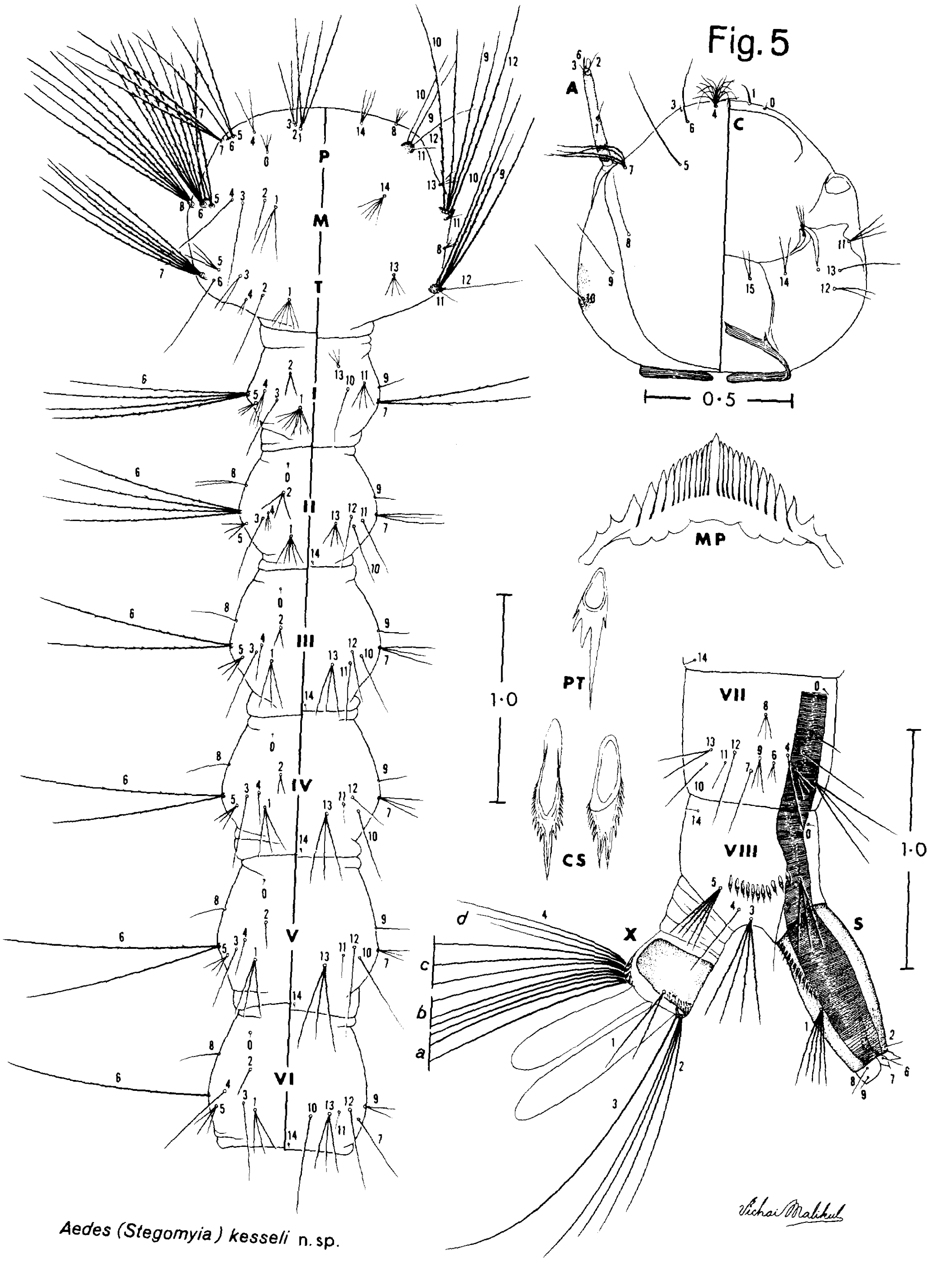
Aedes (Stegomyia) cooki Belkin

Fig. 4



Aedes (Stegomyia) kesseli n.sp.

Fig. 5



Aedes (Stegomyia) kesseli n. sp.

Vichai Malikul

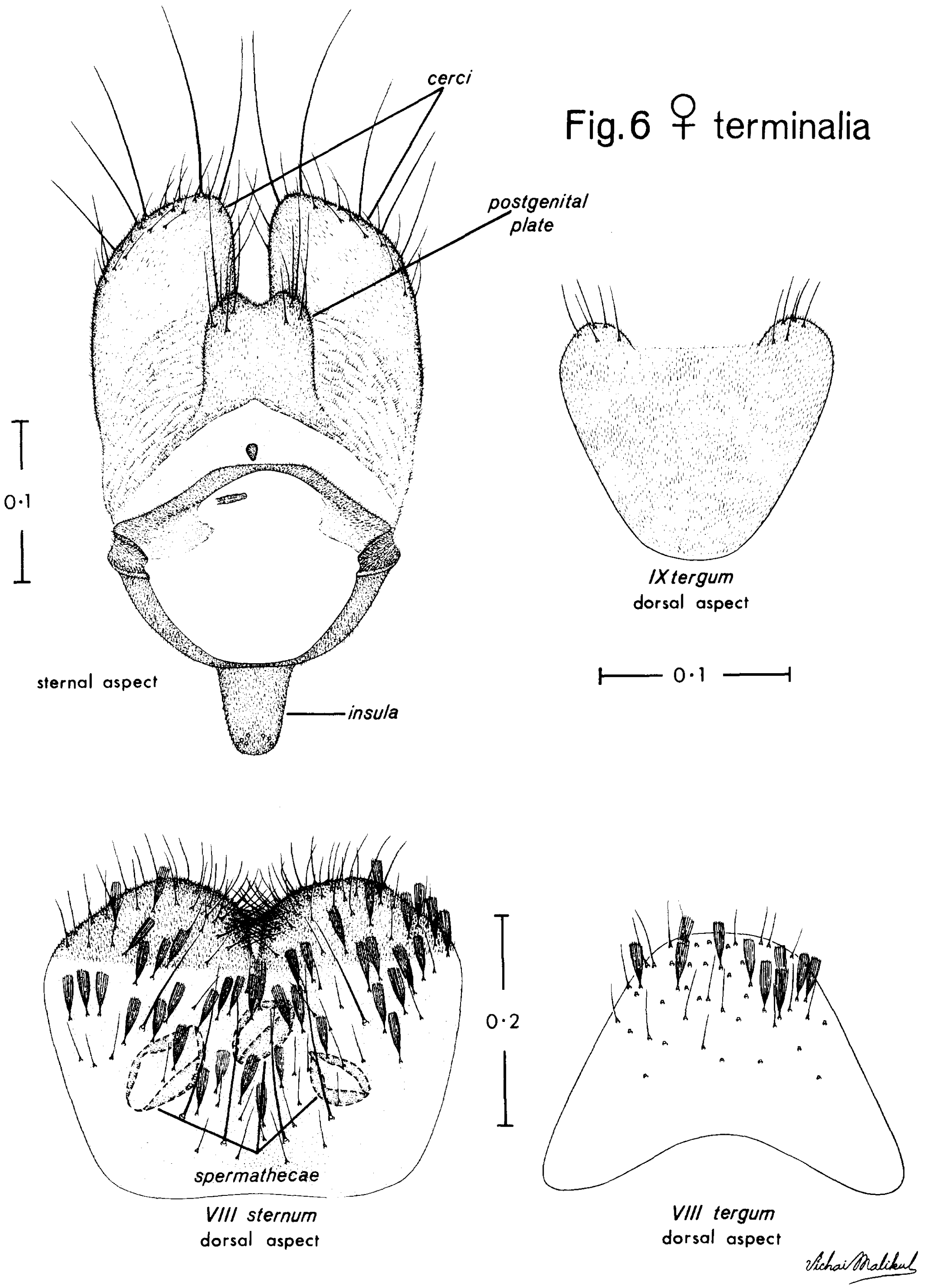
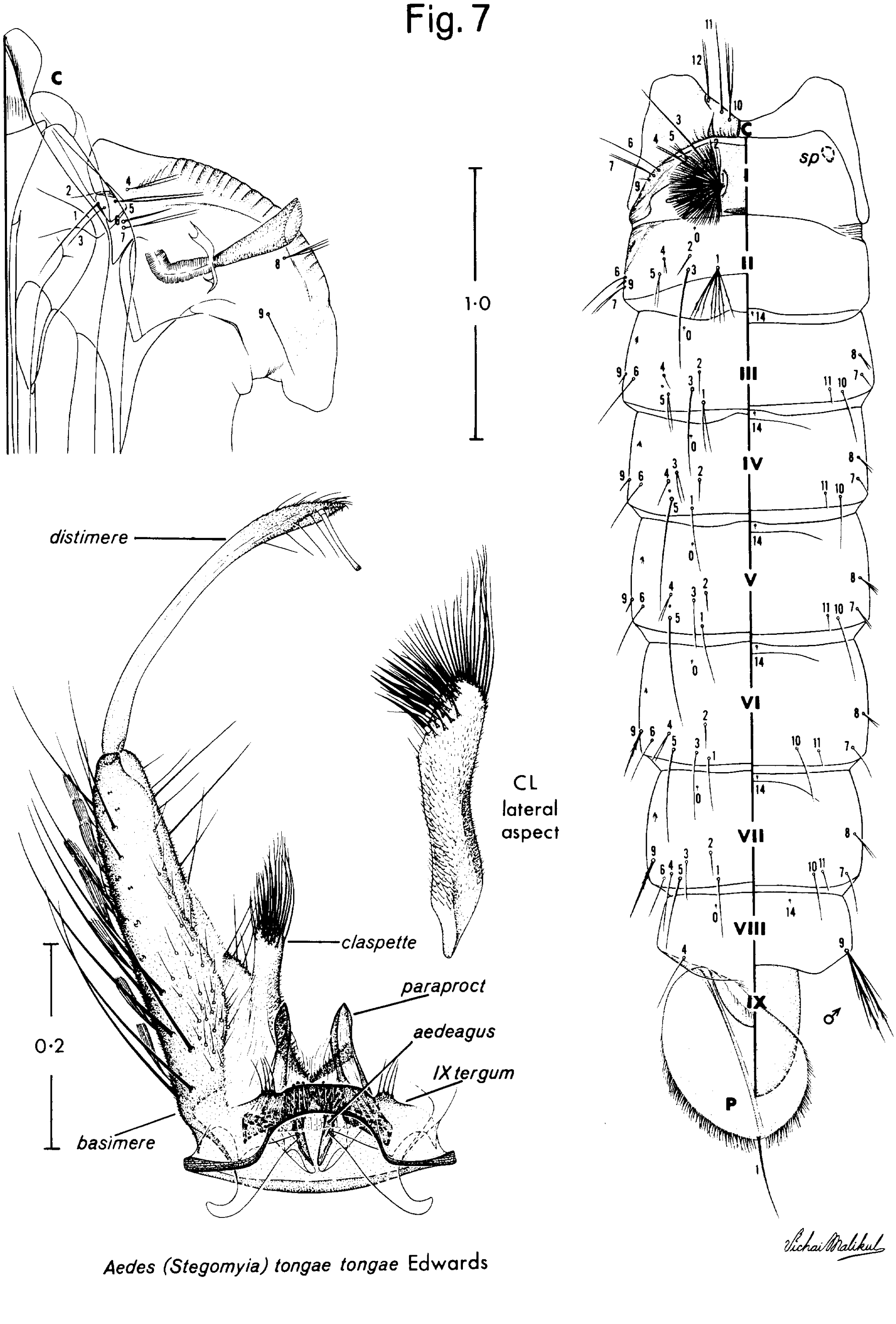


Fig. 6 ♀ terminalia

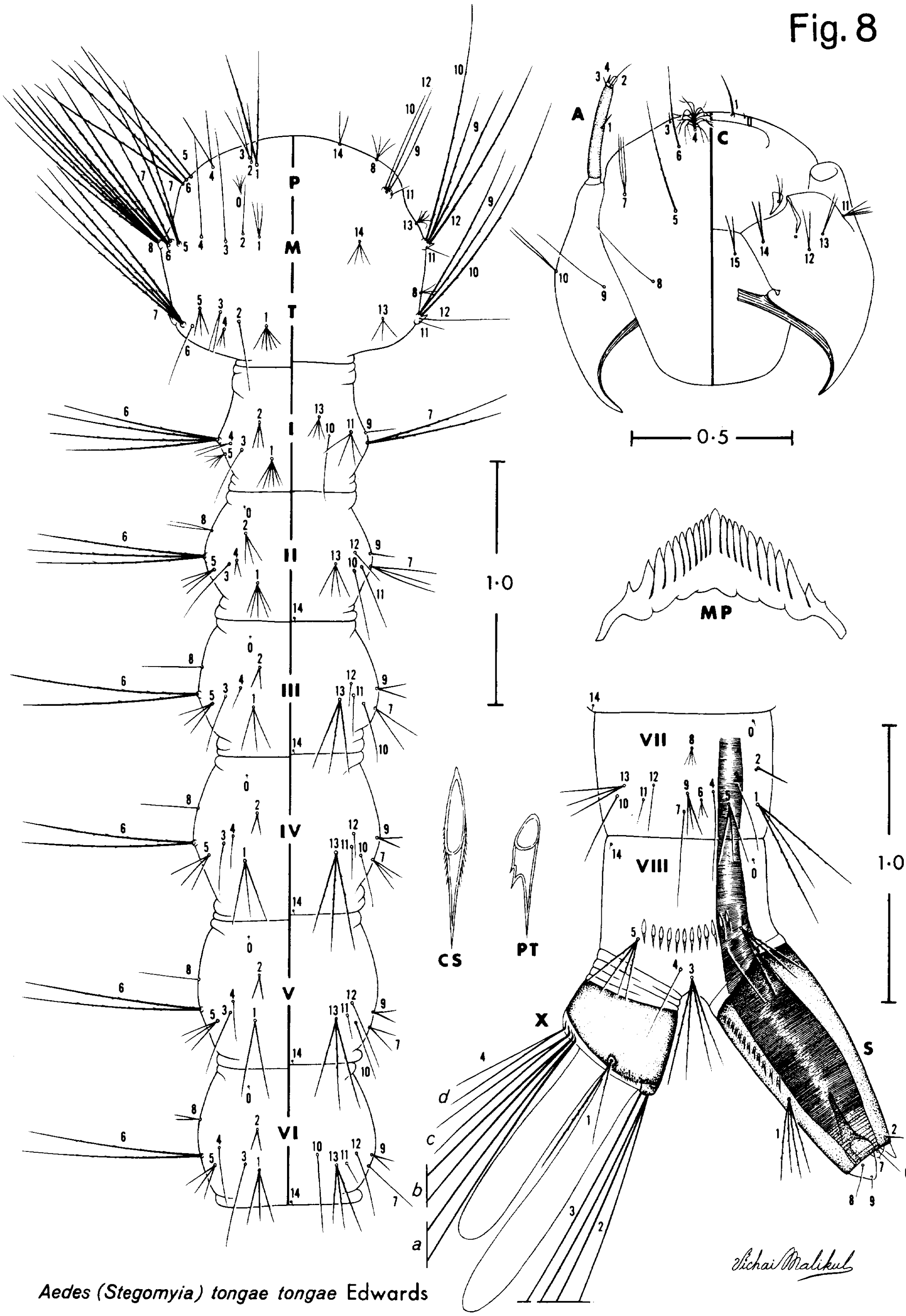
Aedes (Stegomyia) kesseli n. sp.

Fig. 7



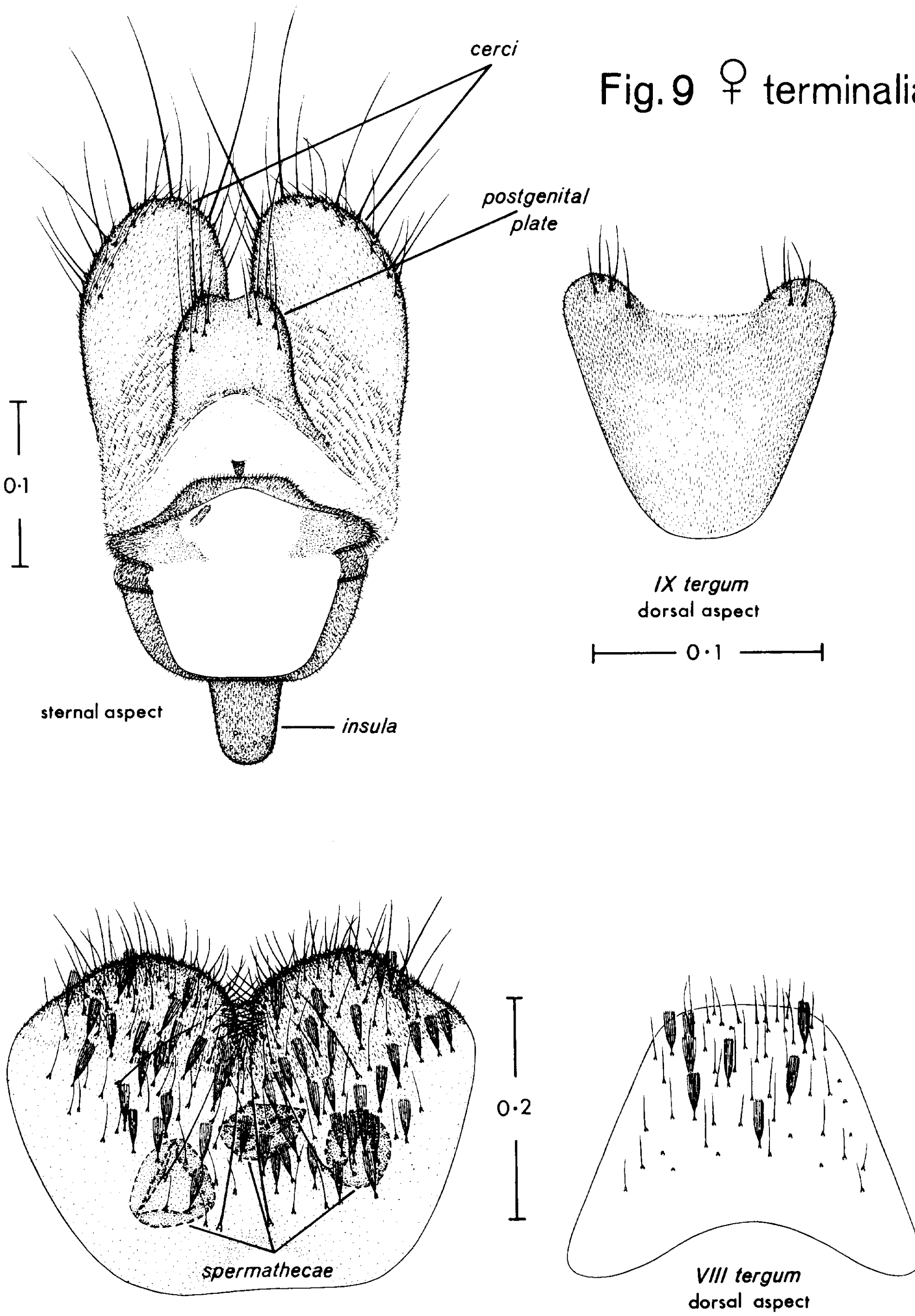
Aedes (Stegomyia) tongae tongae Edwards

Fig. 8



Aedes (Stegomyia) tongae tongae Edwards

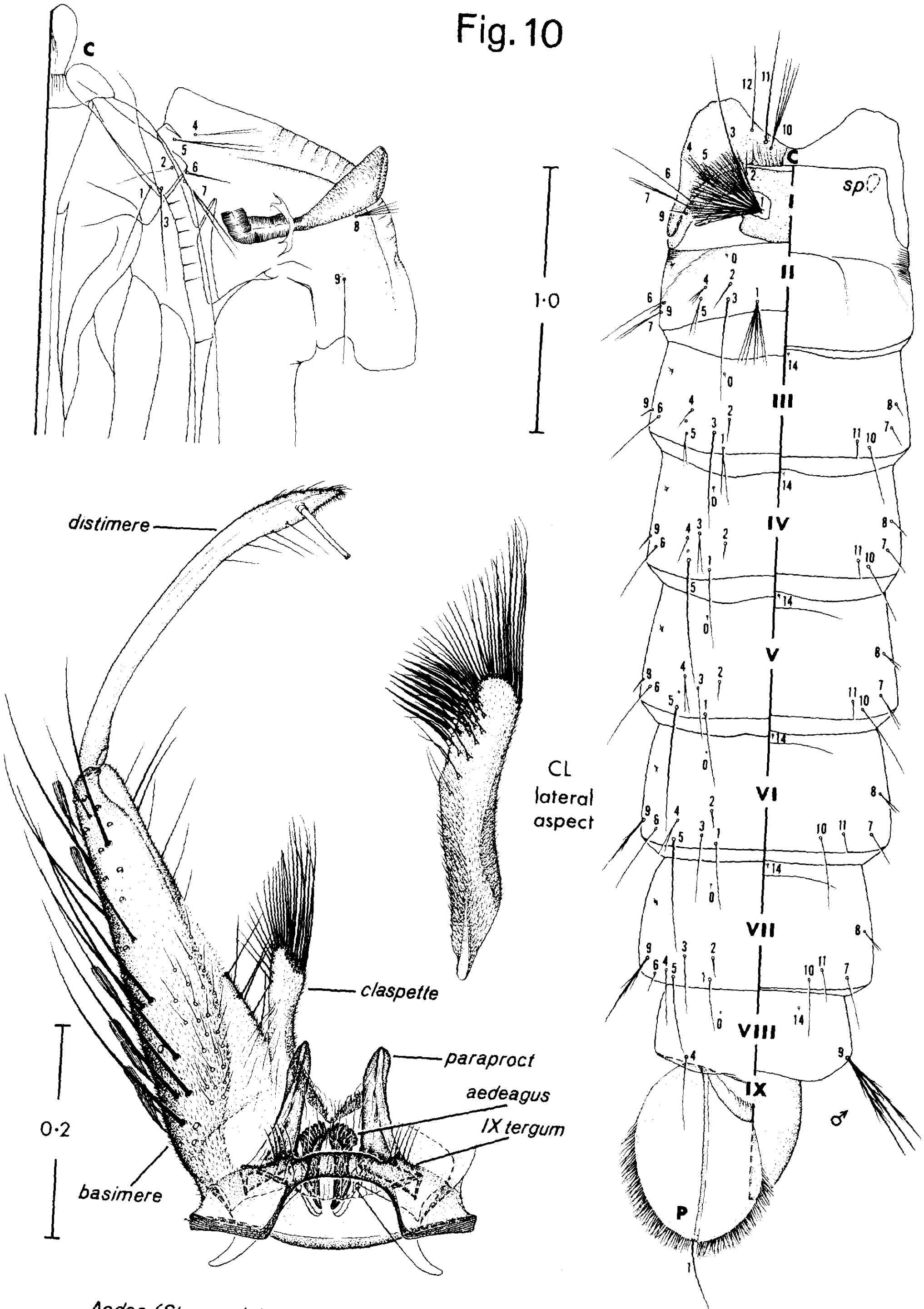
Fig. 9 ♀ terminalia



Aedes (Stegomyia) tongae tongae Edwards

Vichai Malikul

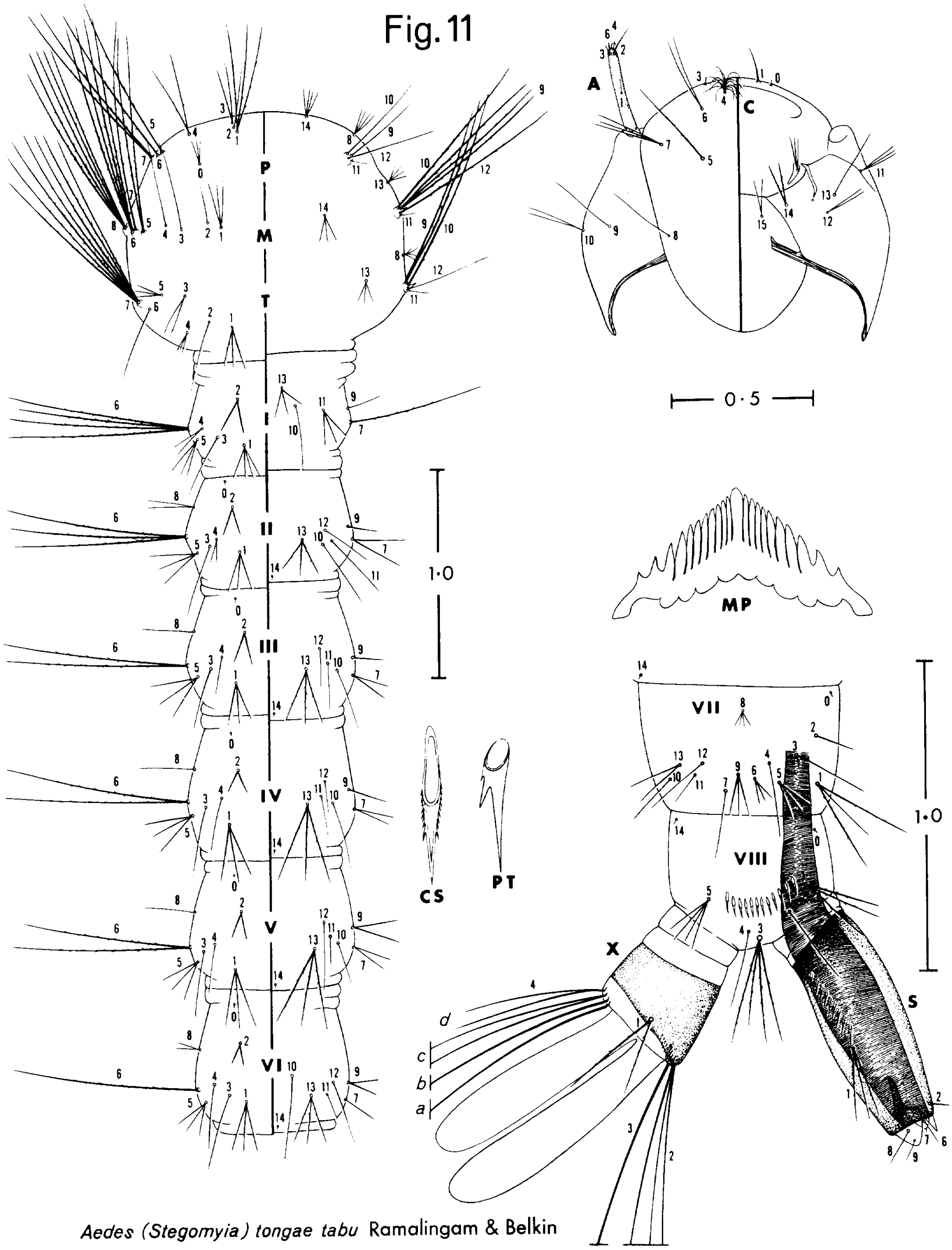
Fig. 10



Aedes (Stegomyia) tongae tabu Ramalingam & Belkin

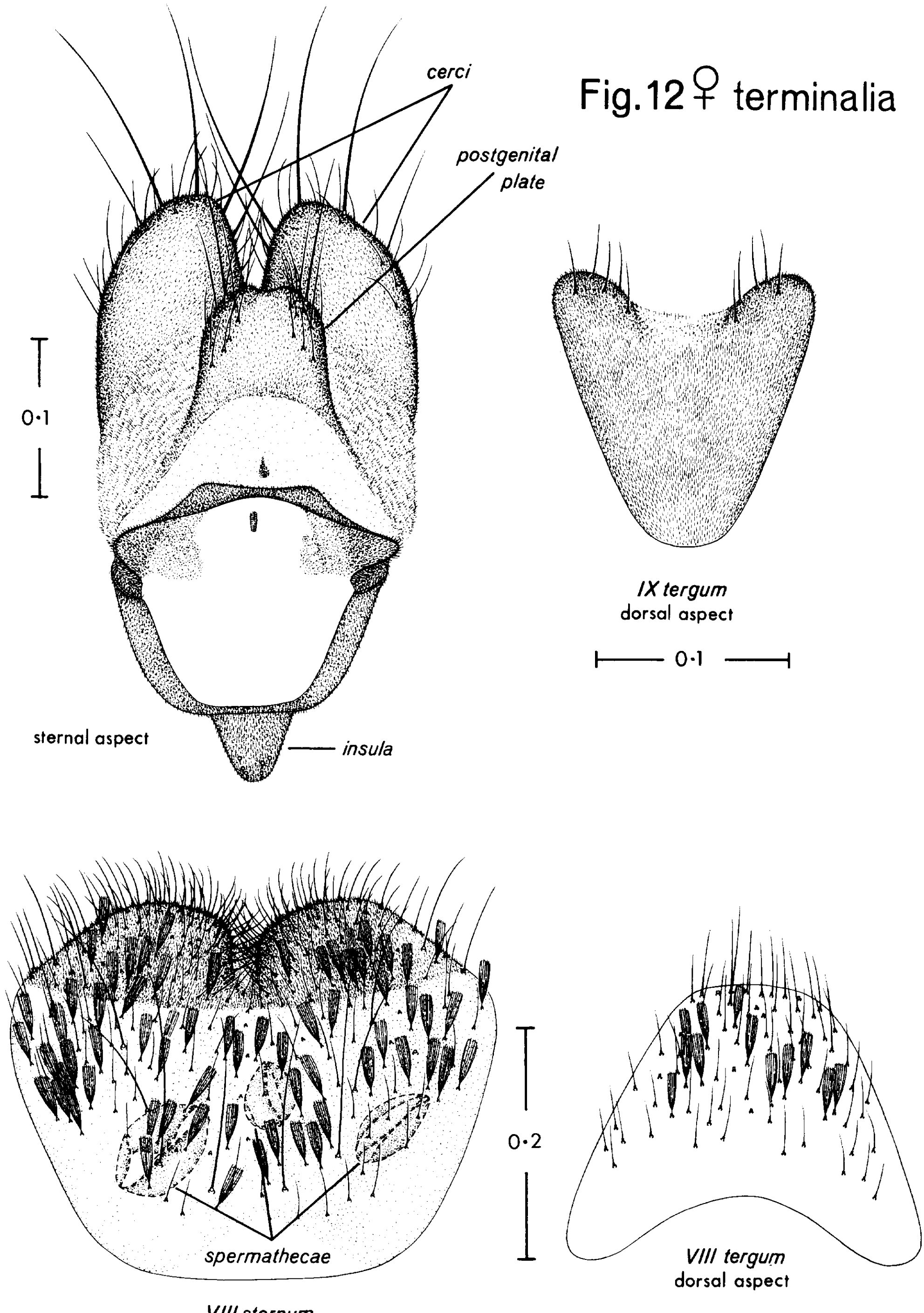
Vichai Malikul

Fig. 11



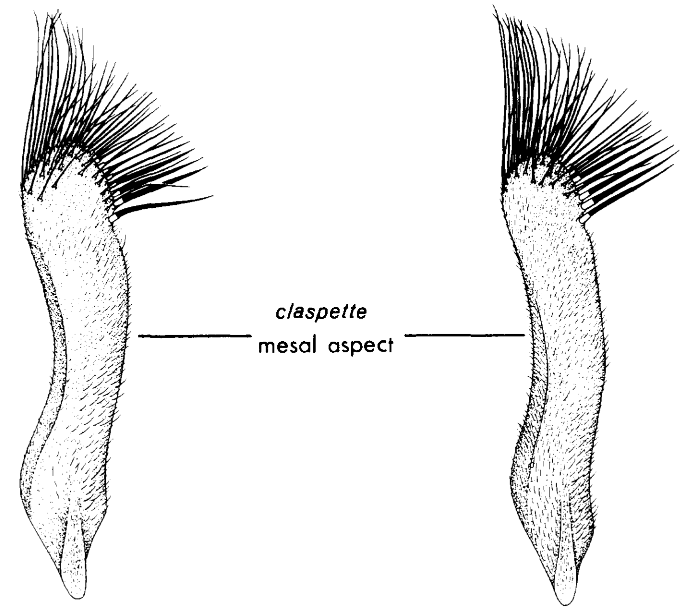
Aedes (Stegomyia) tongae tabu Ramalingam & Belkin

Fig. 12 ♀ terminalia



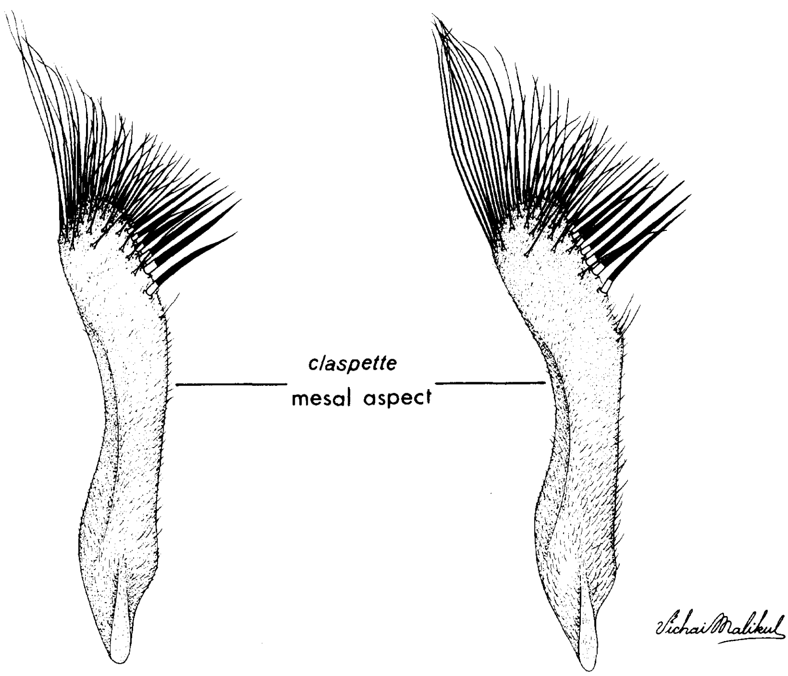
Aedes (Stegomyia) tongae tabu Ramalingam & Belkin

Fig.13 ♂ terminalia



Aedes (Stegomyia) kesseli n. sp.

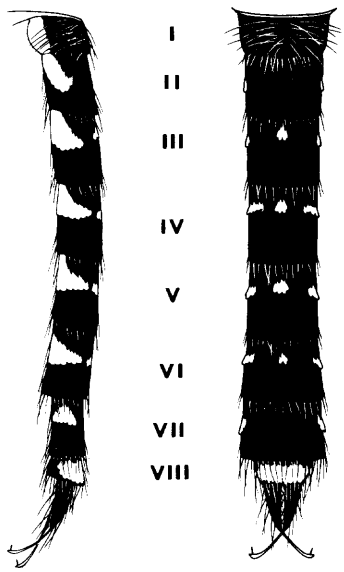
Aedes (Stegomyia) cooki Belkin



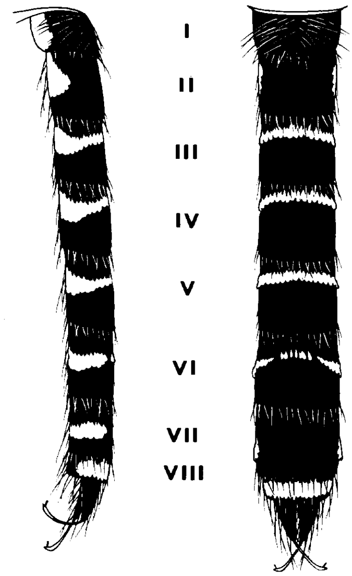
Aedes (Stegomyia) tongae tongae Edward

Aedes (Stegomyia) tongae tabu Ramalingam & Belkin

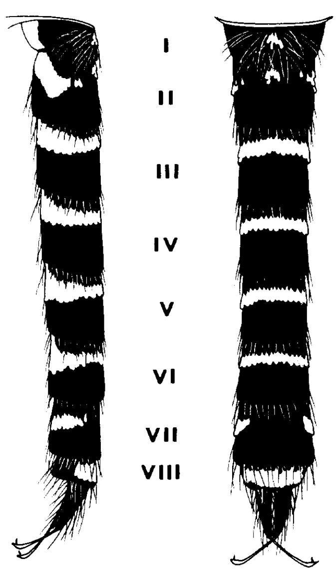
Fig.14 ♂ adult



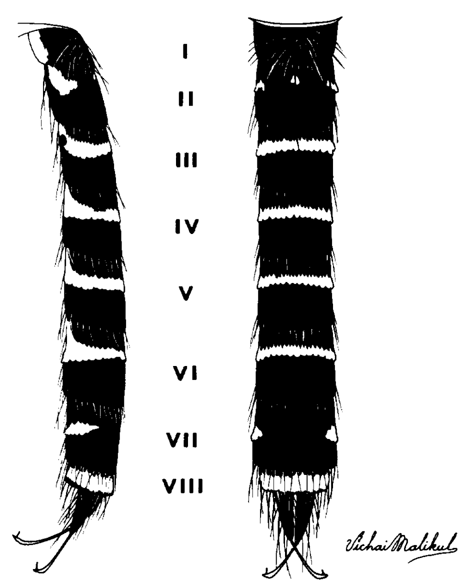
Aedes (Stegomyia) kesseli n. sp.



Aedes (Stegomyia) cooki Belkin

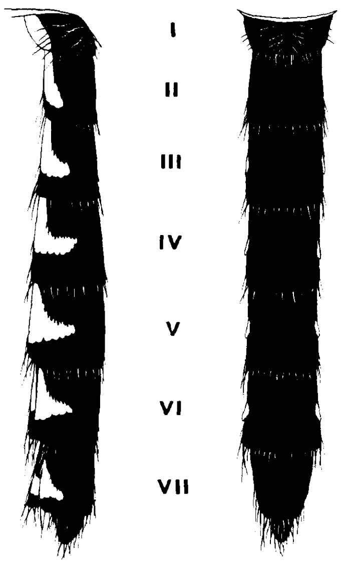


Aedes (Stegomyia) tongae tongae Edwards

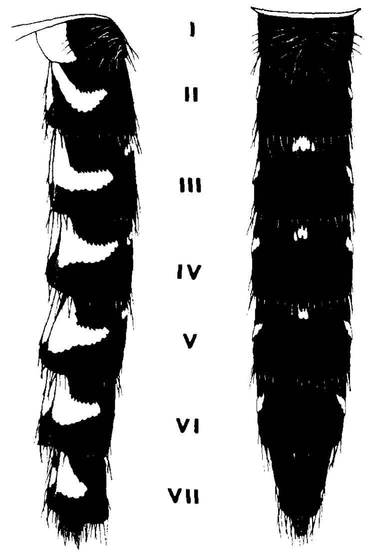


Aedes (Stegomyia) tongae tabu
Ramalingam & Belkin

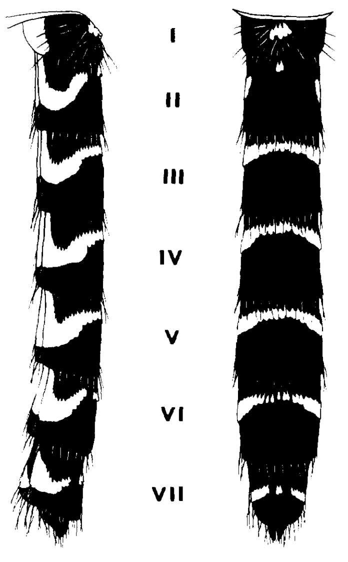
Fig.15 ♀ adult



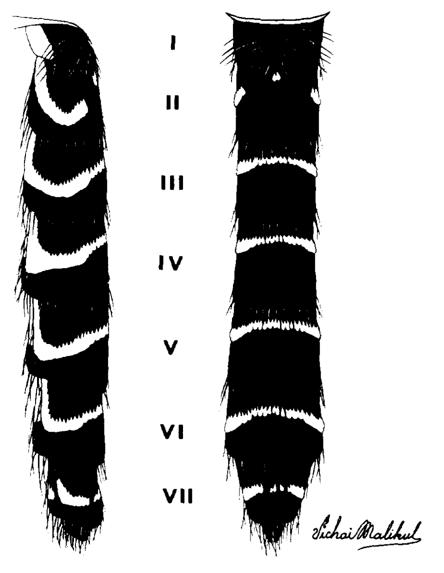
Aedes (Stegomyia) kesseli n.sp.



Aedes (Stegomyia) cooki Belkin



Aedes (Stegomyia) tongae tongae Edwards



Aedes (Stegomyia) tongae tabu Ramalingam & Belkin

Fig.16 Hindlegs & thorax

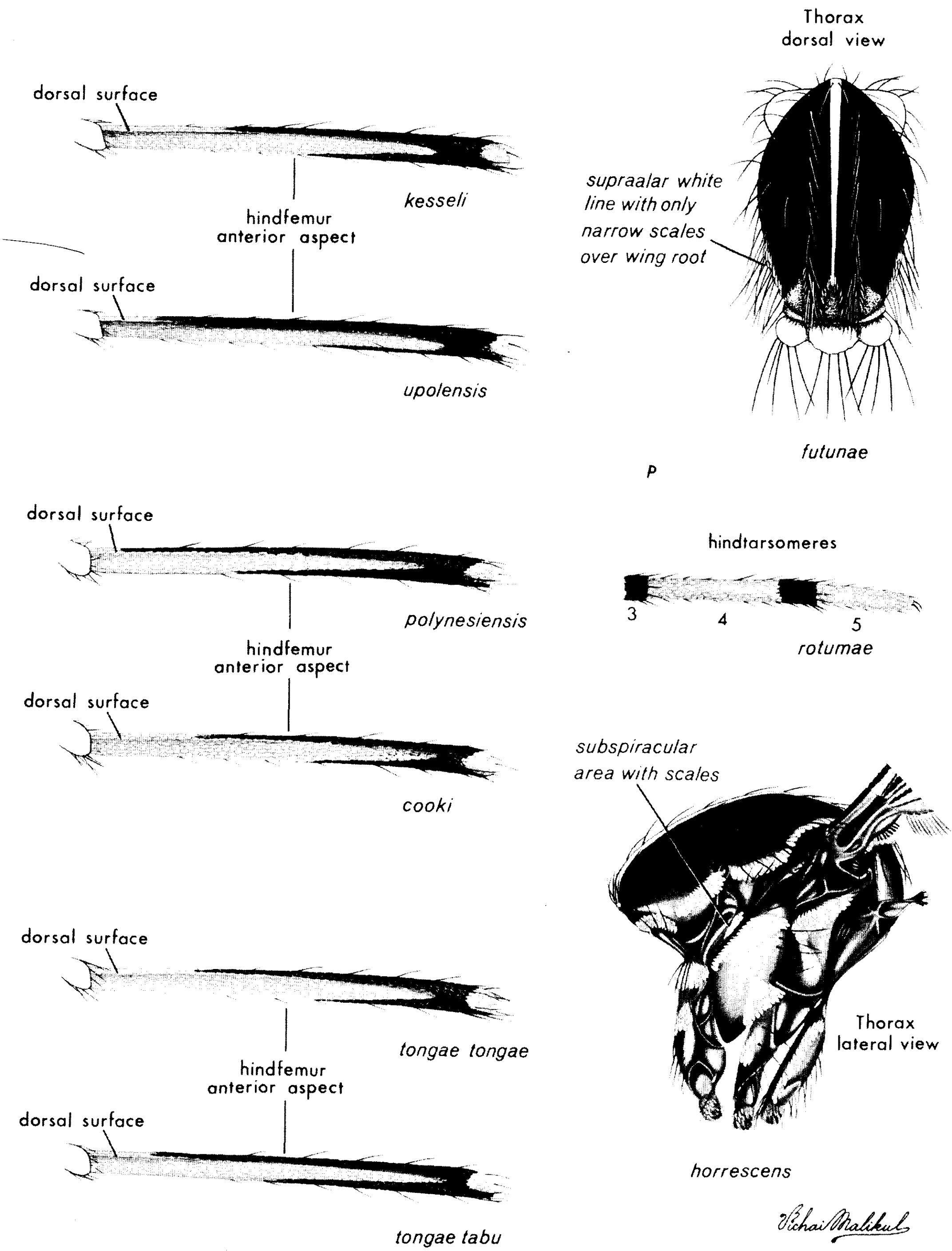
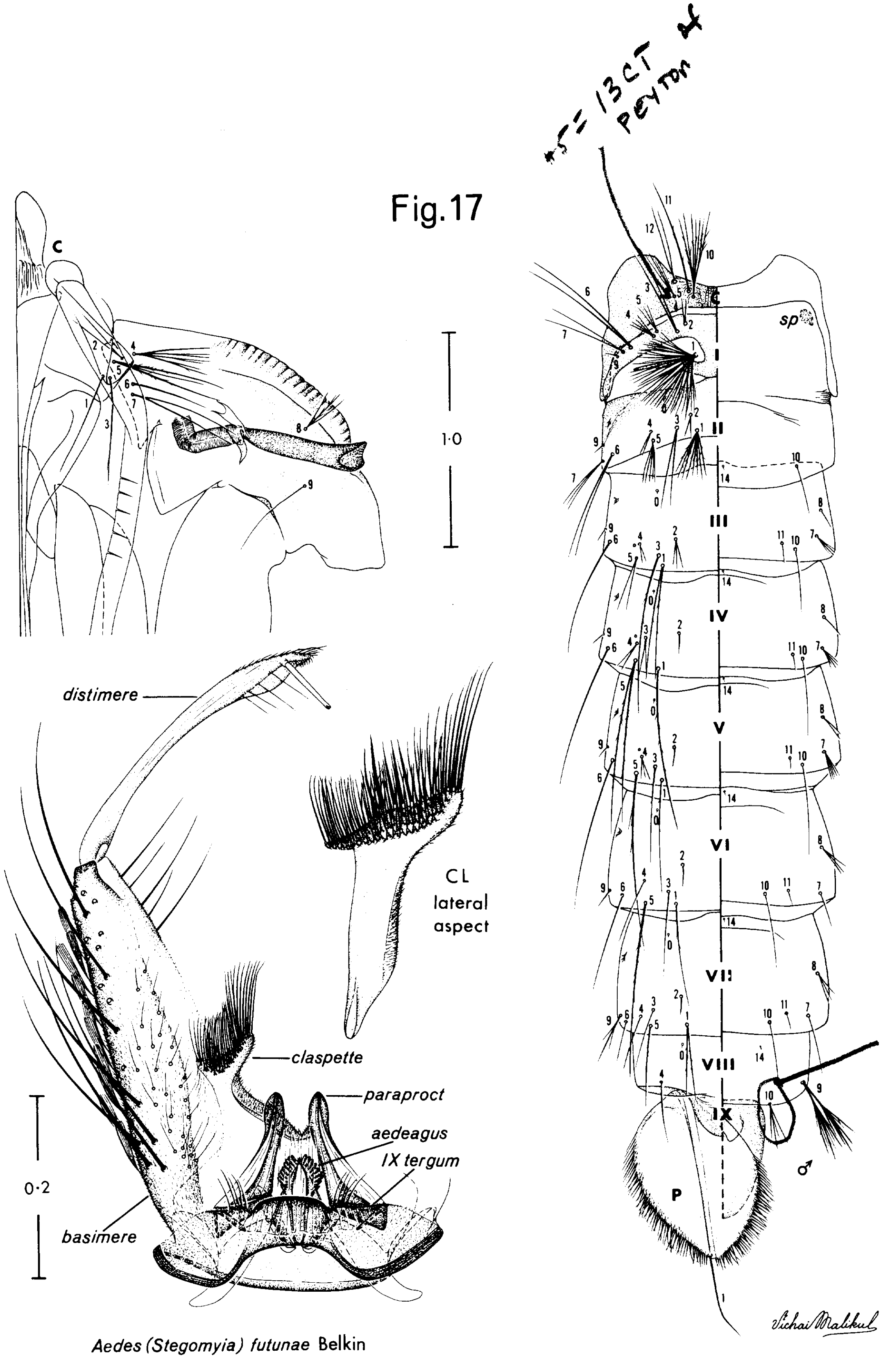
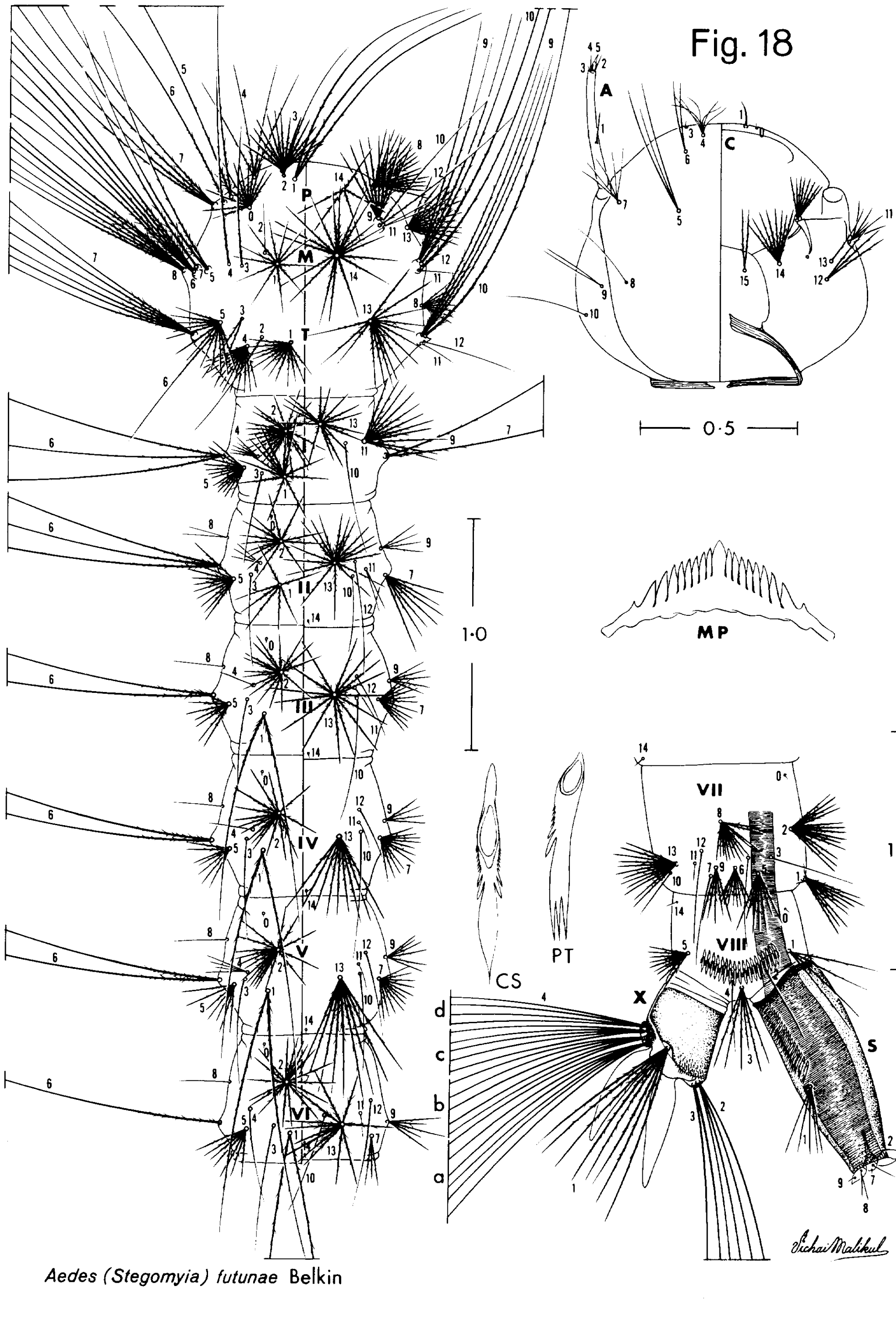


Fig.17



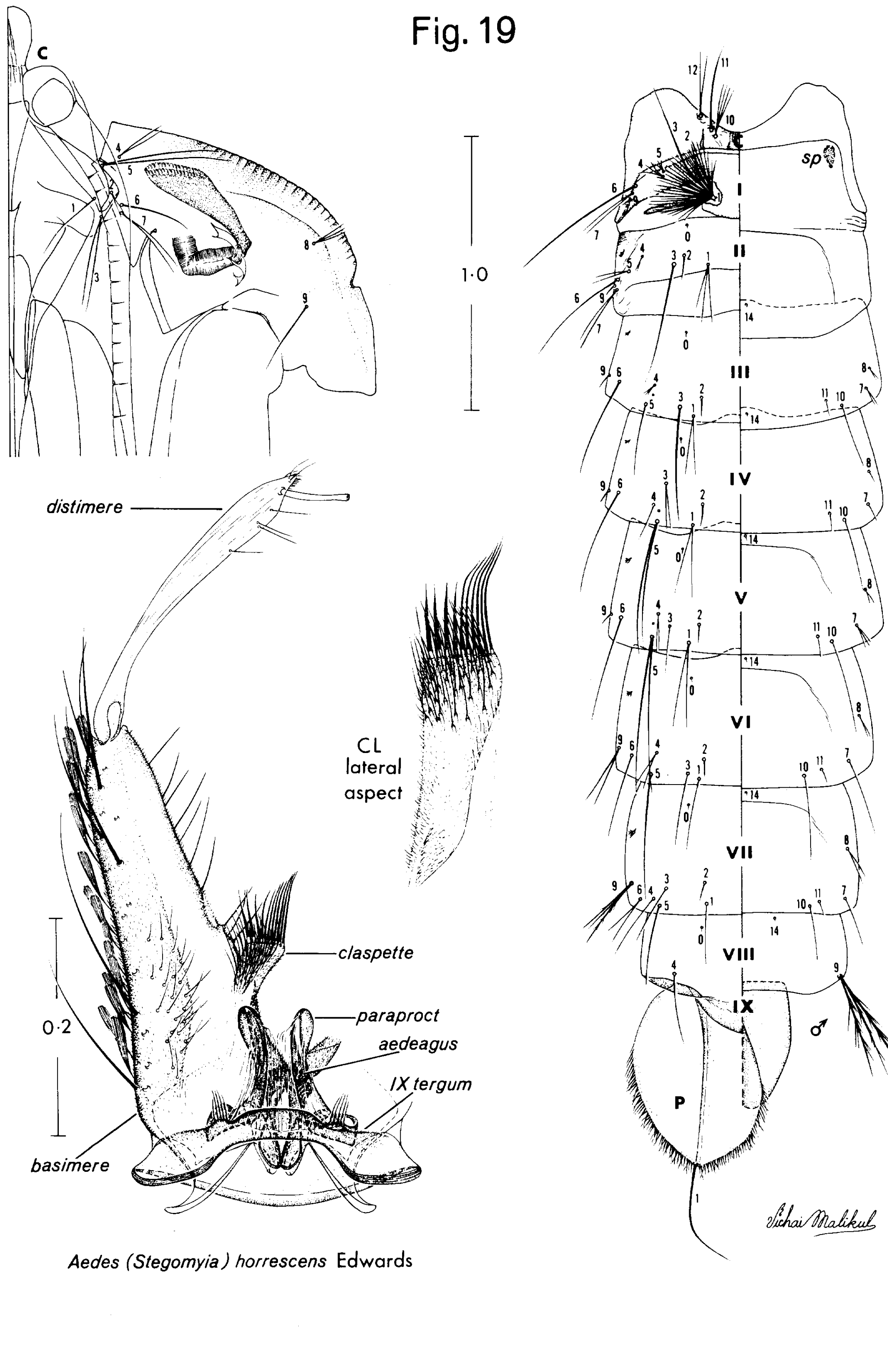
Aedes (Stegomyia) futunae Belkin

Fig. 18



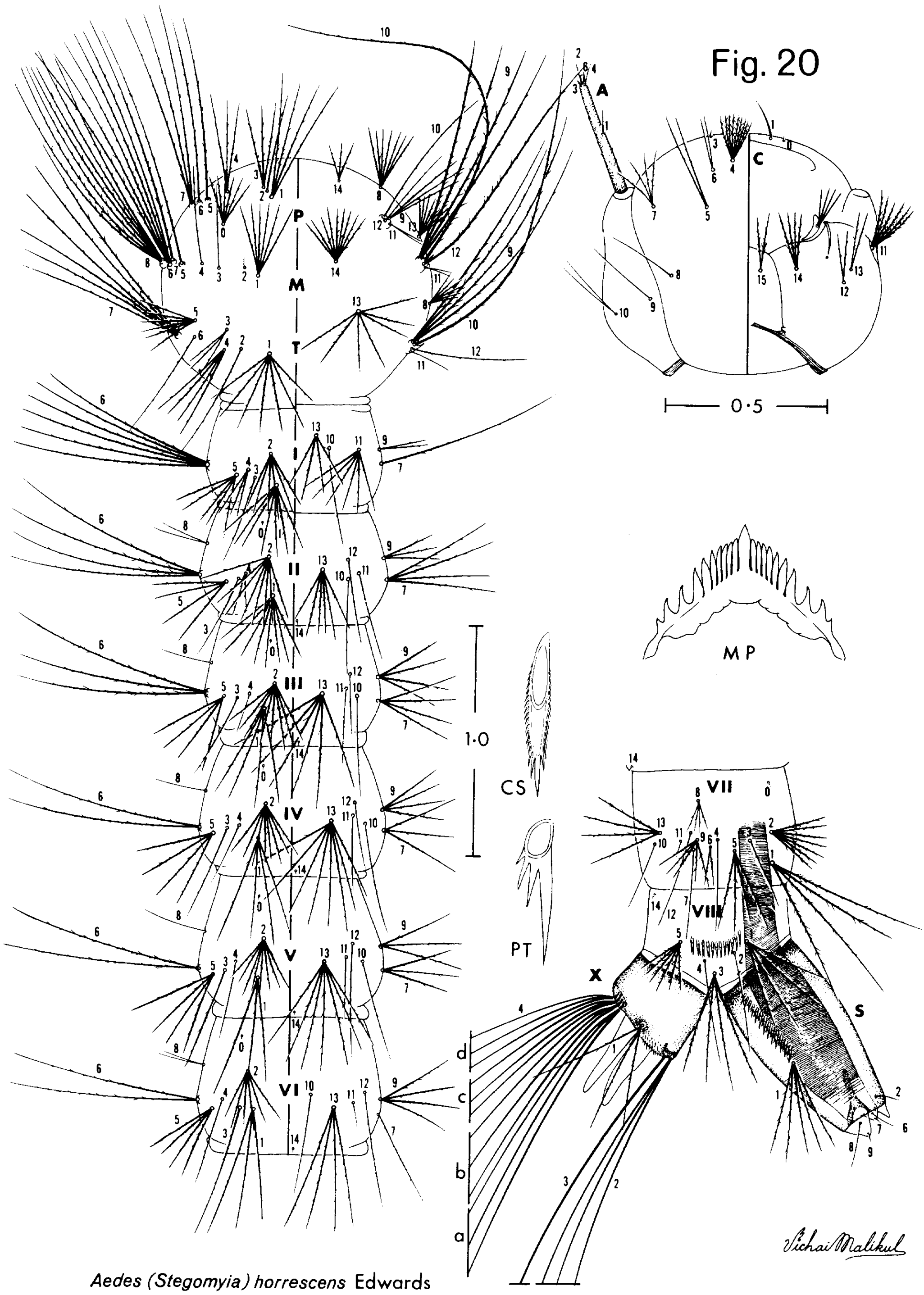
Aedes (Stegomyia) futunae Belkin

Fig. 19



Aedes (Stegomyia) horrescens Edwards

Fig. 20



Aedes (Stegomyia) horrescens Edwards

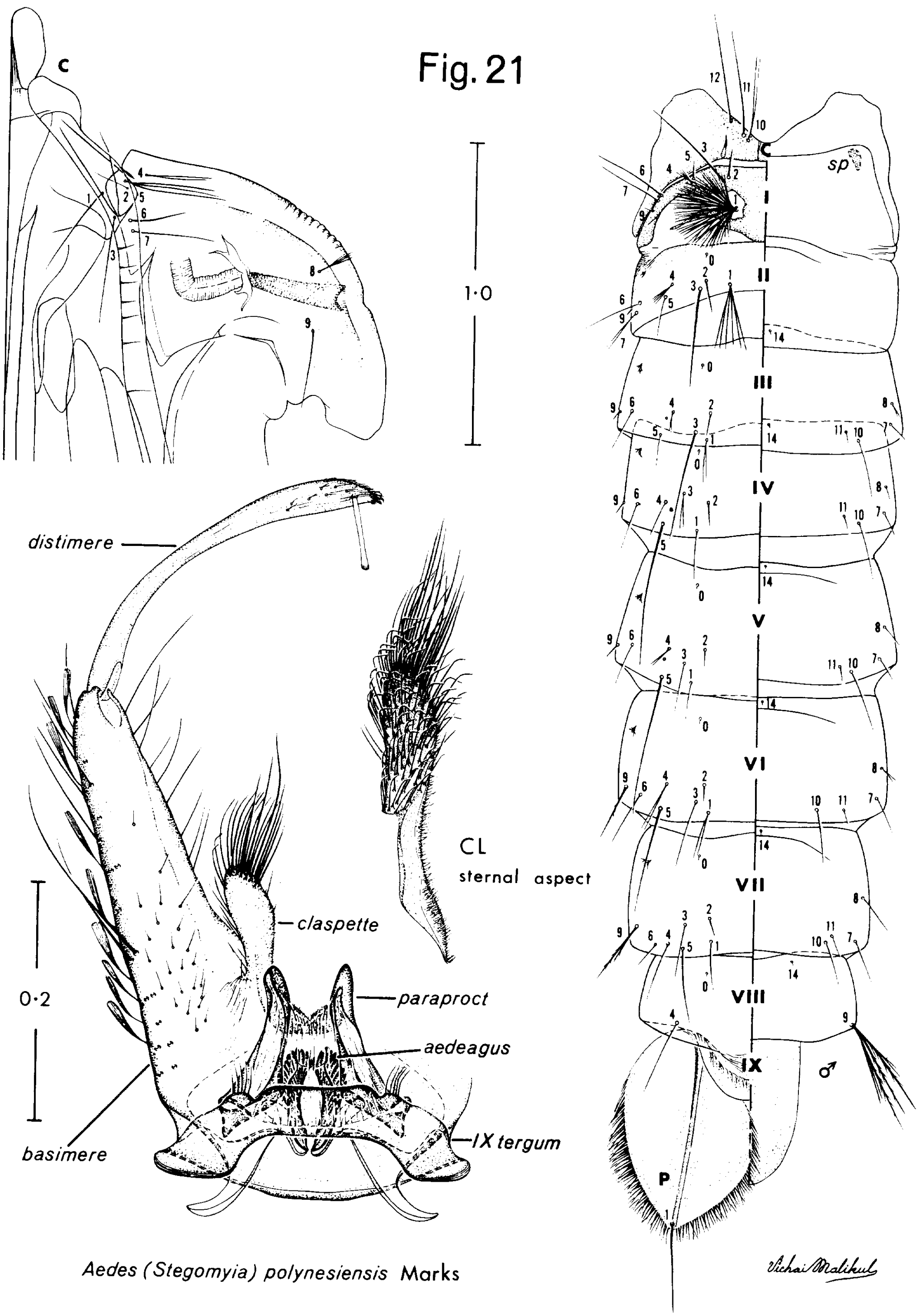
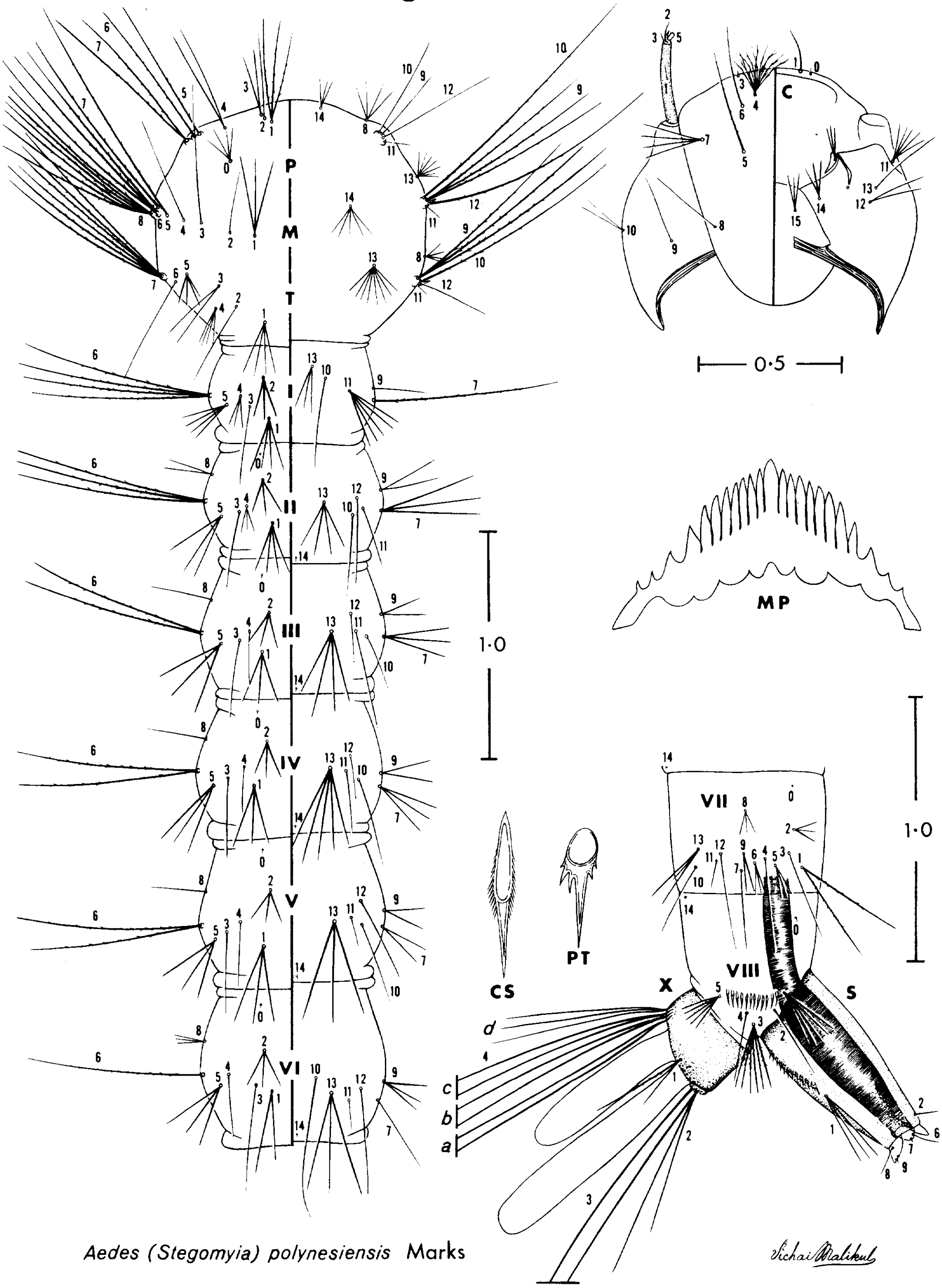


Fig. 21

Aedes (Stegomyia) polynesiensis Marks

Fig. 22



Aedes (Stegomyia) polynesiensis Marks

Vichai Malikul

Fig. 23 Thorax, hindfemur & claspette

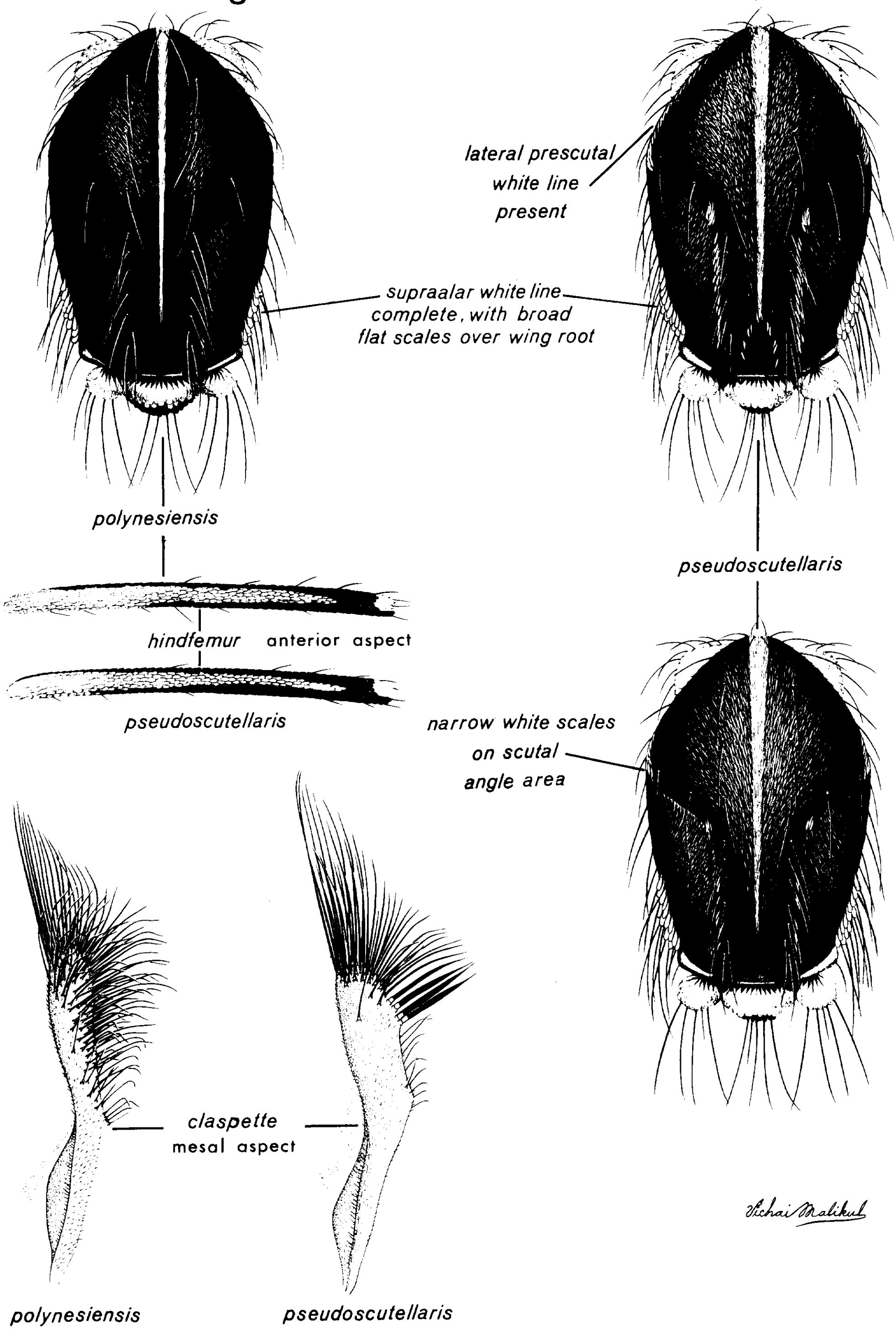
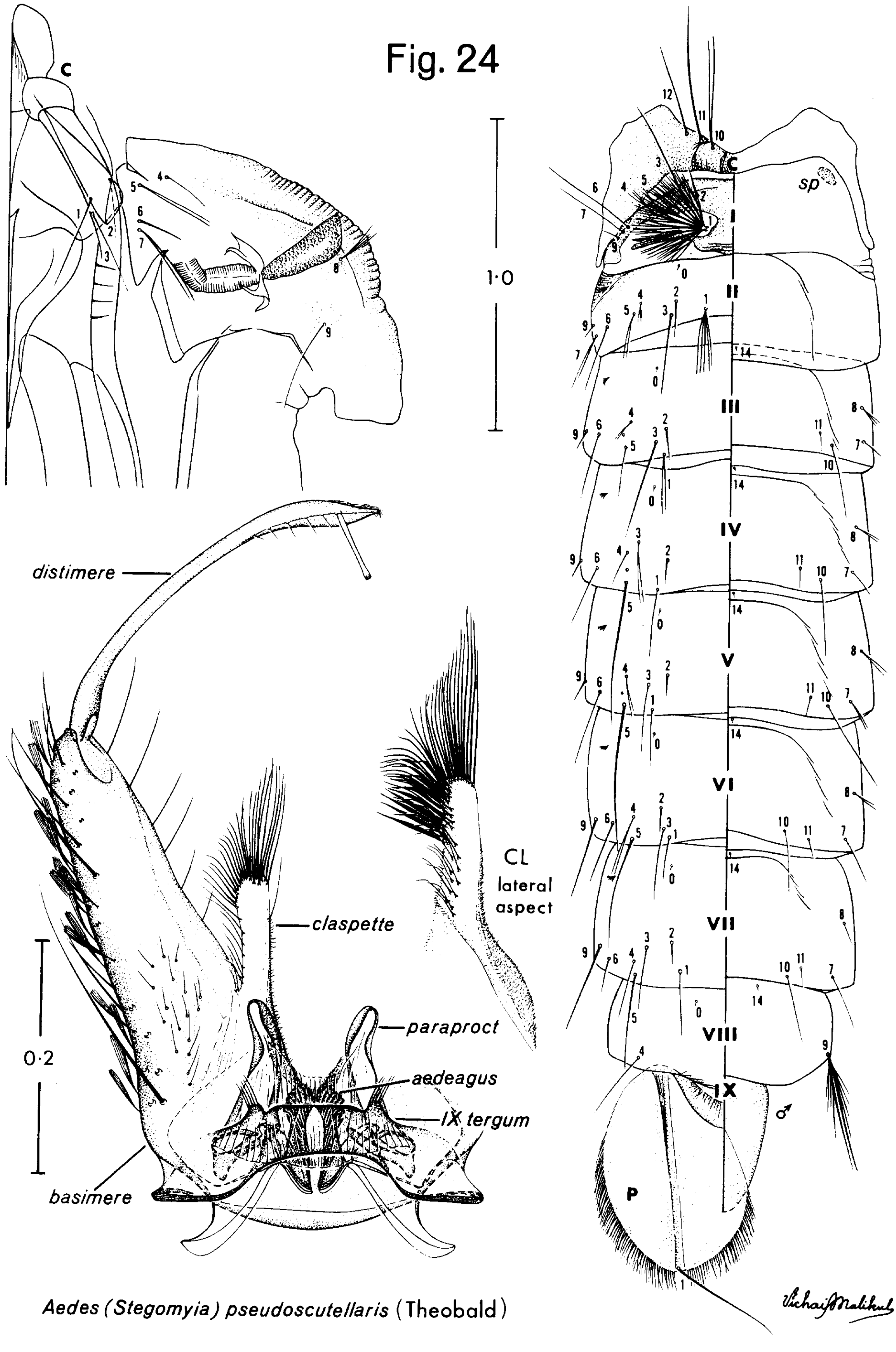
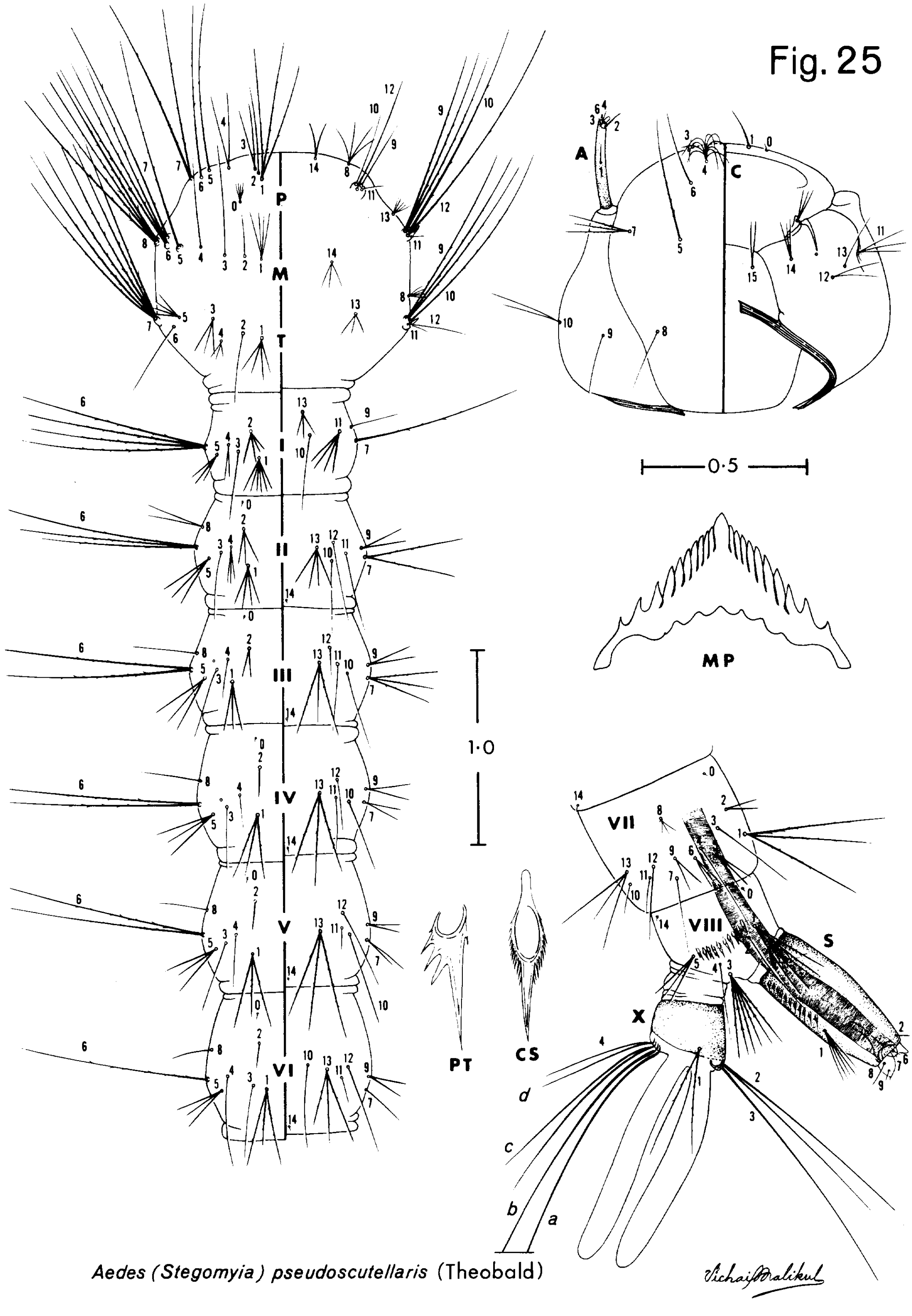


Fig. 24



Aedes (Stegomyia) pseudoscutellaris (Theobald)

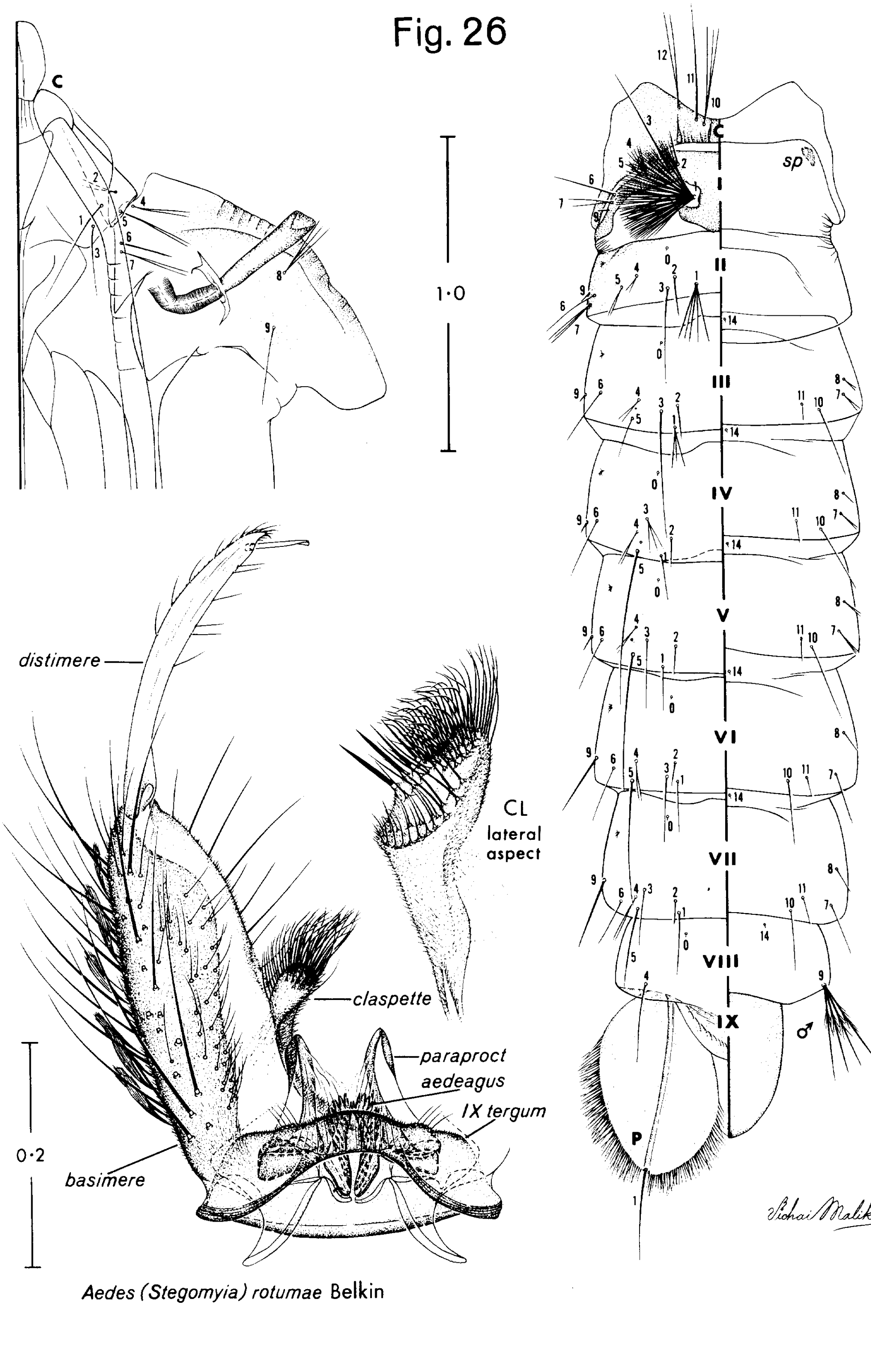
Fig. 25



Aedes (Stegomyia) pseudoscutellaris (Theobald)

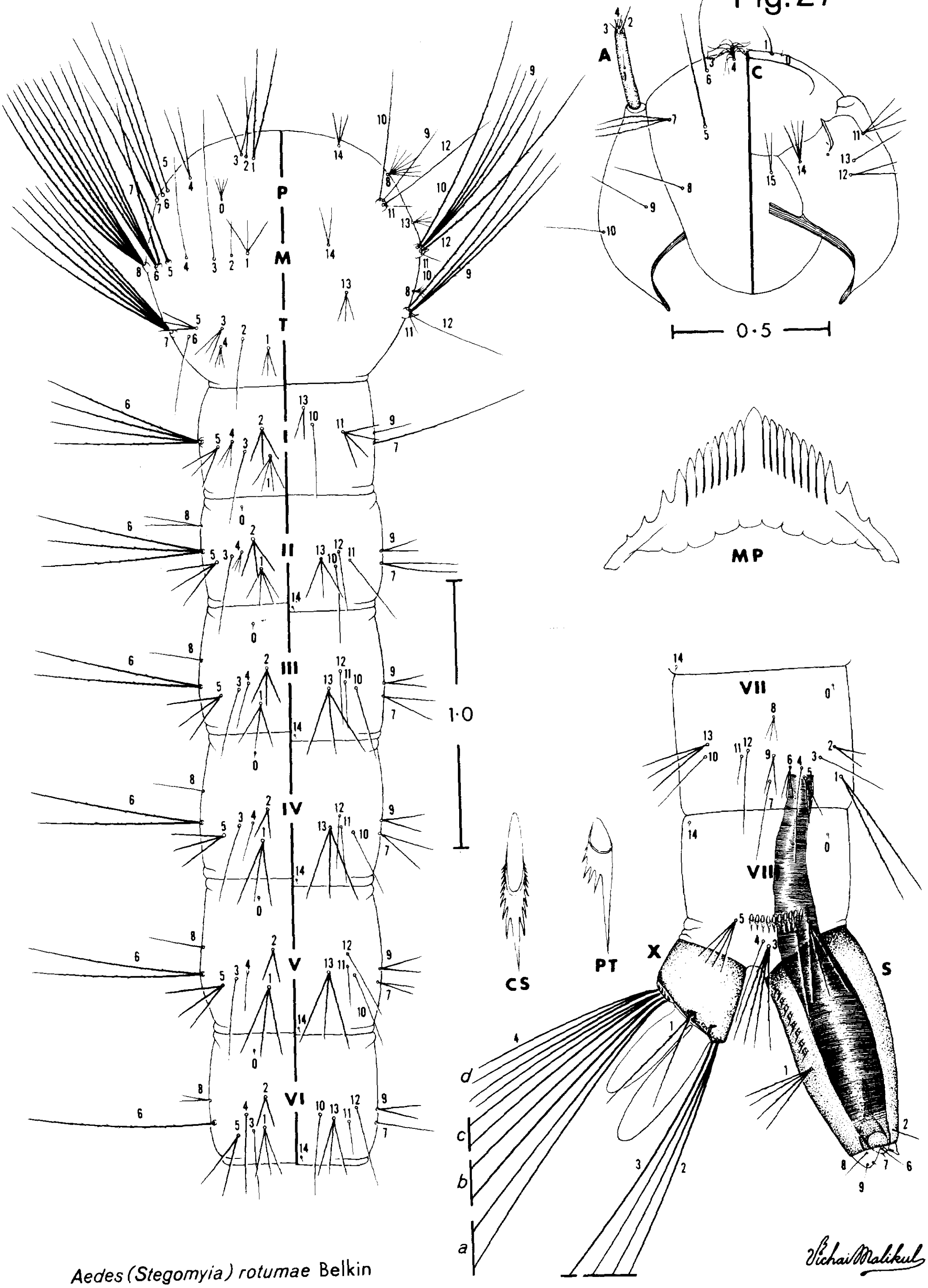
Vichai Malikul

Fig. 26



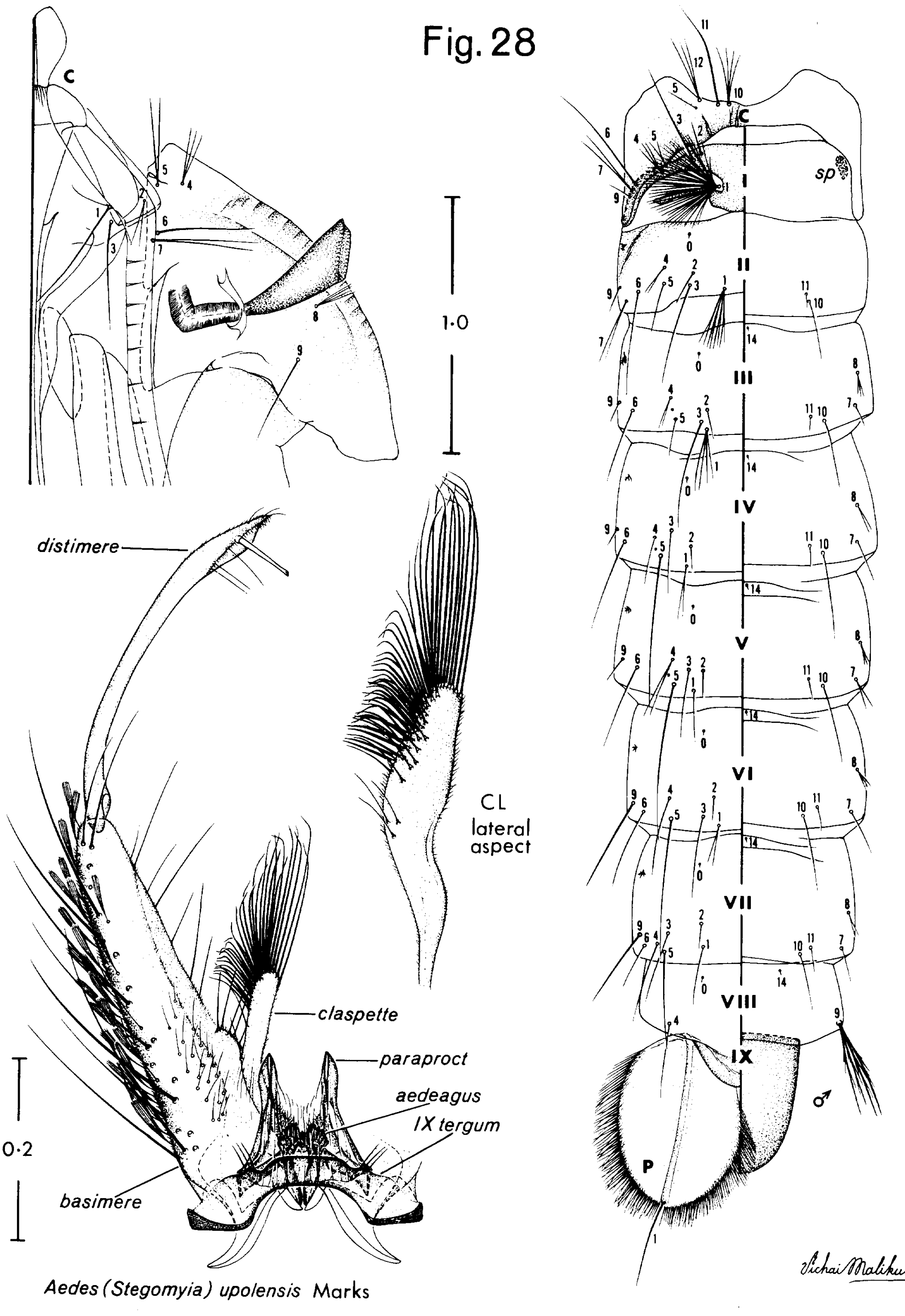
Aedes (Stegomyia) rotumae Belkin

Fig. 27

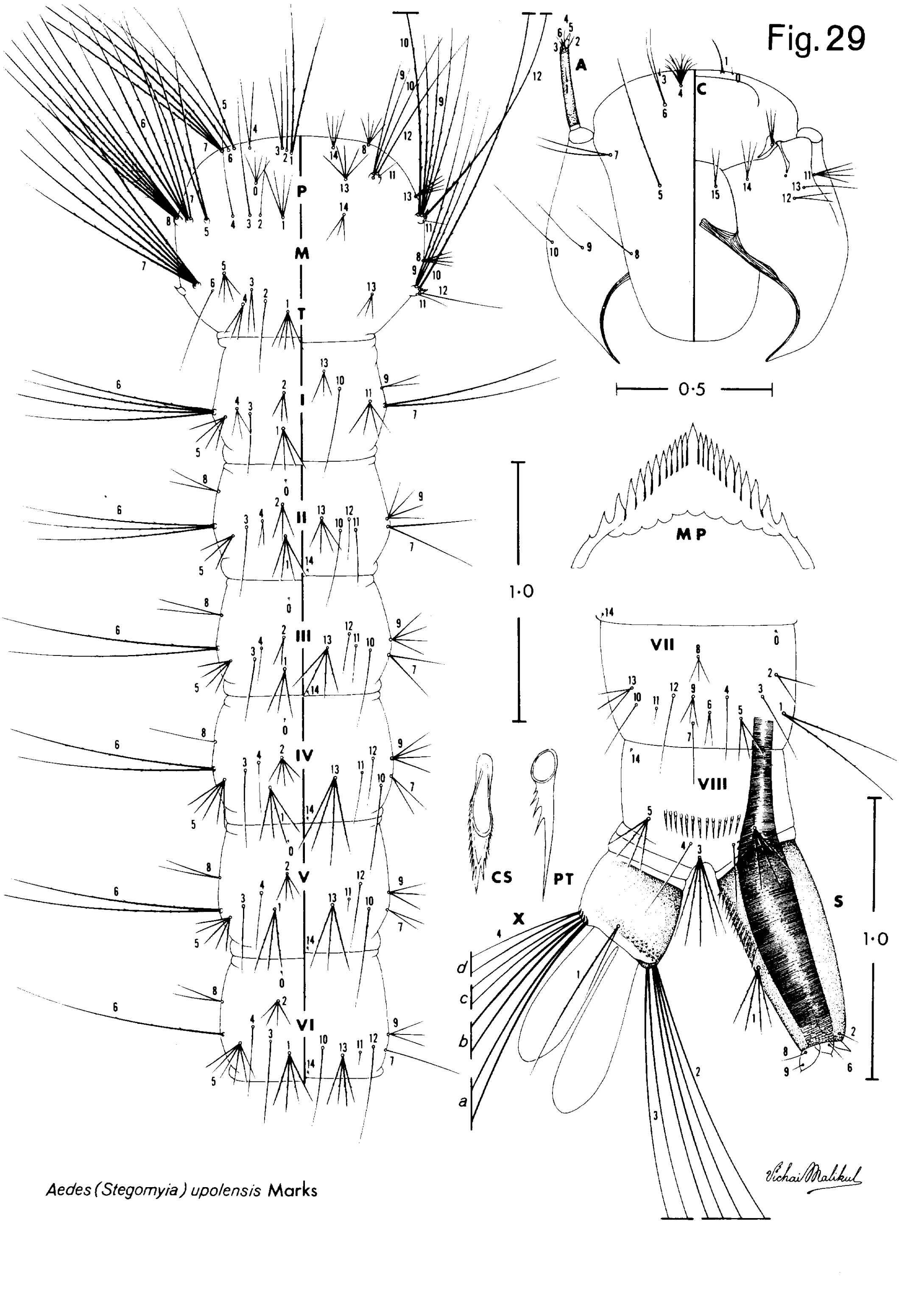


Aedes (Stegomyia) rotumae Belkin

Fig. 28



Aedes (Stegomyia) upolensis Marks



Aedes (Stegomyia) upolensis Marks

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Names of valid taxa are set in roman type; synonyms, misidentifications, etc. are in italicized type. Italicized numerals refer to the principal text references. Roman numerals refer to secondary text references; the suffix "k" indicates mention in a key and the suffix "t" indicates mention in a table. Roman numerals in parentheses without a suffix refer to the figures. The prefix "Map" designates the distribution is illustrated on a map.